THE CHINESE UNIVERSITY OF HONG KONG

FINAL REPORT

FOR

THE PROVISION OF SERVICE FOR THE STUDY OF HEALTH EFFECTS OF TRANSPORTATION NOISE IN HONG KONG

ENVIRONMENTAL PROTECTION DEPARTMENT, HKSAR GOVERNMENT

TENDER REF. AN 08-047

Submitted by Professor Kin Che Lam on behalf of the Centre for Environmental Policy and Resource Management of the Chinese University of Hong Kong

January 2012

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Principal Investigator:

Noise: Professor Kin Che Lam[1]

Co-investigators:

Noise (international): Professor Lex Brown[2]

Medical: Professor Tze Wai Wong[3]

Epidemiology (international): Dr. Irene van Kamp[4]

Statistical: Professor Ying Keung Chan[5]

[1]Department of Geography and Resource Management, The Chinese University of Hong Kong
[2]Griffith School of Environment, Griffith University, Australia
[3]Division of Occupational and Environmental Health, The Chinese University of Hong Kong
[4]The National Institute of Public Health and the Environment, The Netherlands
[5]Department of Sociology, The Chinese University of Hong Kong

ACKNOWLEDGEMENTS

The consultancy team would like to thank all those who have assisted in the preparation and production of this report, particularly Ms. Yi-tak Teresa Chung (Research Officer and Project Coordinator), Mr. Chor Hei Tsang Byford, Mr. Wai Fung Wong and Mr. King Lam Chung.

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Executive summary

Commissioned by the Environmental Protection Department of the Government of the Hong Kong Special Administrative Region, this study investigates the health effects of transportation noise in Hong Kong. Among the various effects of noise, WHO highlighted annoyance, sleep disturbance and cardiovascular disease. This is the first systematic city-wide study in Hong Kong and one of the few in the world using the ISO/TS 15666 protocol on survey methodology. The study attempts to identify the key health effects of transportation noise by reviewing the recent scientific literature and undertaking a large scale survey of the Hong Kong population using carefully thought out sampling strategy and interview technique.

This study was supported by a separate noise mapping exercise assessing the noise exposure levels of the whole city and a social survey implemented by the Census and Survey Department of the Government of the Hong Kong Special Administrative Region as part of their "thematic survey" studies. A total of 10,077 households were successfully interviewed and noise exposure level assessed. This study team designed the questionnaire and trained the interviewers of the social survey.

In undertaking the study, the study team was keenly aware of the need to design a questionnaire that will provide the data required to address the study objectives and for possible comparison with previous similar studies. The International Organisation for Standardization (ISO/TS 15666) standards in setting and posing questions in the survey were strictly adhered to; and a meticulous protocol had been developed to ensure that all questions were professionally posed; carefully framed and diligently executed. A quality assurance scheme was in place to ascertain validity and assurance accuracy.

As part of the Government's "thematic survey" program, a scientific sampling frame, akin to random sampling, was adopted to cover the whole of Hong Kong. While such a strategy will provide reliable and accurate estimates of people adversely affected by transportation noise, it might not give adequate coverage on all transportation noise sources (e.g. aircraft and rail) and the low, medium and high exposure groups at the same time. This is nonetheless a useful and effective attempt given severe time and resource constraints and the current study must be considered the first systematic survey of noise effects for Hong Kong. Given these constraints, the current study focused on road traffic noise – its extent and its effects on Hong Kong population. It is suggested future studies can be extended to rail and aircraft noise but a different sampling approach, stratified to cover rail and aircraft noise, is suggested.

In addition to the noise exposure and self-reported annoyance and sleep disturbance data, the study has also collected a large array of related data on noise sensitivity, sleep pattern, health, noise coping behavior and self-reported noise sources. They are useful not only to explain the findings of this study, but also to provide insight on living habits of the population in a dense compact city.

The large sample size enabled the team to determine that 28.9% and 36.2% of the sampled dwellings are exposed to road traffic noise in excess of $L_{10,1h}$ 70 dBA and L_{DEN} 65 dBA respectively at the most exposed dwelling facade. The latter is the first ever estimate made in Hong Kong. The study has also ascertained that noise is the most often complained issue of the living environment. On the other hand, a good acoustic environment is the 4th most important aspect urban living. These public aspirations appear to be significant as the survey also found out that about 30% of the Hong Kong population reported having sleep problems. The survey has also found that among the adult population in Hong Kong, 856,100 (or 14.4% of the adult population) are annoyed by road traffic noise either throughout the whole day or at night; or are sleep disturbed. Among them, 327,000 are adversely affected at night, reporting that they are either highly annoyed or their sleep is highly disturbed, by traffic noise. A small proportion of them, amounting to 189,000, are both highly annoyed and highly sleep disturbed.

Besides road traffic noise, which is regarded by 7.9% of the adult population as highly annoying, the Study has found that high annoyance is also caused by other environmental noise sources. Among them, 10.8% of the Hong Kong adult population felt highly annoyed by renovation noise. The corresponding figures for construction and demolition noise are 3.5% and 3.4% respectively.

The Study found that 4.95% of the adult population was highly annoyed by road traffic noise at night. The corresponding figure for neighborhood noise is 1.7%. Noise of outside animals accounted for high annoyance in 1% of the adult population.

Concerning noise sources which cause sleep disturbance, the Study has found that road traffic noise and neighborhood noise at night are the first and second mostly mentioned ones, accounting for 4.15% and 1.4% of the adult population respectively. The third most frequently reported source causing annoyance was noise from outside animals accounting for about 0.7% of the adult population.

The above figures suggest that quite a sizeable proportion of the Hong Kong population are adversely affected by road traffic noise; an issue which warrants the attention of the Government given the potential health consequences. From the results of the annoyance reaction of the public in the Study, it appears that renovation noise could be one of the priority areas that the Government may like to tackle.

While it is tempting to compare the Hong Kong estimates with those of other places and countries, it has been underscored in this report that very few data are currently available for comparison because most of the previous studies were undertaken at a time when there was no standardized questions and no adequate attention was given to sampling strategy and data quality (Fields et al., 2001).

In comparison with those using similar methodology, it is observed that the annoyance response of the Hong Kong population seems to be not as strong as Miedema's. The Hong Kong response curve is nonetheless comparable to those derived for two Vietnamese cities.

It is intriguing to speculate why there is a discrepancy between the response observed in Hong Kong and those obtained previously in Europe. Whether or not the discrepancy is culturally related or coping behavior modified are issues awaiting further investigation. Previous sociological studies have demonstrated that the Hong Kong population are more tolerant to high density living. One cannot dismiss the possibility that the less strong reaction can be attributed to window closing and air conditioning which can magnify the indoor-outdoor noise difference and reduce indoor noise exposure. The study team further observed that window closing and air conditioning is income-biased and no policy or standard should be changed without considering the differential effects on a particular class of the society that is relatively deprived and vulnerable.

The study also explored and elucidated factors which may intensify or moderate annoyance or sleep disturbance reactions. The results for noise annoyance and sleep disturbance are broadly similar. The study has ascertained, as in similar previous studies, that noise exposure intensifies annoyance reaction only slightly. The factor which tends to make one highly annoyed and/or sleep disturbed is sensitivity to noise. On the other hand, factors which can moderate and reduce annoyance reaction and sleep disturbance include satisfaction with the neighborhood environment and having access to a quiet room in the dwelling. These two factors have been recognized in the literature, highlighting the fact that human response depends not only on the exposure at the place of residence but also the overall environmental quality in the neighborhood. The Government could consider managing the noise annoyance by creating a good "overall acoustic environment" rather than relying only on reducing the noise exposure at the dwellings. At the same time, it is noteworthy that most of the socio-economic factors, such as age, gender, education and income, have very little, if not absolutely no, effect on human annoyance and sleep disturbance. It should also be noted that window closing has been found to be an intensifier of annoyance and sleep disturbance reactions. No definitive explanation can be given because window closing can be the causative factor as well as the outcome. Statistical analyses can only determine the association between the two but not to determine whether one causes the other or vice versa. Again this is another area which merits further investigation.

To conclude, the study has ascertained that road traffic noise is a problem with possible health effects in Hong Kong. A sizeable proportion of the population is adversely affected. There is some indication that the annoyance and sleep disturbance responses are not as strong as those reviewed by Miedema. However, the Hong Kong response is comparable to those of Vietnam cities. The study has also ascertained that human response is determined only to a small extent by noise exposure. It is shaped by a large number of other non-acoustic factors. This calls for careful re-examination of the conventional approach to manage the acoustic environment by mere noise reduction.

The study is the first systematic survey of the possible health effect of transportation noise in Hong Kong. It is among one of the very few of its kind in the world. Findings of the study are significant both locally and internationally. The estimates obtained in this study are reliable; and findings are sound because of the scientific rigor in questionnaire design and sampling. All these findings will contribute significantly to policy making and to the scientific community. They are essential for the creation of a sustainable urban environment of which sound is a vital component.

Chapter One: Introduction

1.1 Background

Excessive noise can adversely affect human health and interferes with people's everyday lives. About 40% of the population in the European Union (EU) countries is exposed to road traffic noise at levels exceeding 55 dB. Recent evidence from the World Health Organization (WHO, 2009; WHO, 2011) shows that the transportation noise is harming the health of one-third of Europeans, and one-fifth is regularly exposed to sound levels during night time which could significantly damage health. The Guidelines for community noise (Berglund et al., 1999) underscore the need to maintain a good acoustic environment which assures quality sleep and be free from interference with daily activities and noise-induced cardiovascular effects.

An earlier study undertaken by the Environmental Protection Department (EPD) estimated that about 18% of the Hong Kong population was exposed to road traffic noise in excess of $L_{10,\ 1h}$ 70 dB(A) (EPD, 2006), the noise planning standard in Hong Kong. However, little research on the health effects of transportation noise has been studied in the Asian region, including Hong Kong. It is therefore high time for Hong Kong to keep abreast of the latest scientific understanding of the health effects of noise; to review the work and practices of other countries; and to survey the noise effects on local population, so as to assist in the policy making in Hong Kong.

The Chinese University of Hong Kong was commissioned by the Environmental Protection Department of the Hong Kong Special Administrative Region Government to undertake this consultancy study according to the Tender Ref. AN 08-047 "The Study of Health Effects of Transportation Noise in Hong Kong" (hereafter the study).

1.2 Objectives

This study aims to undertake:

- A review on three non-auditory health effects, namely annoyance, sleep disturbance and cardiovascular diseases, based on the literature available from the WHO, the EU and the USA, other published work and papers, relevant research findings and related studies;
- Based on the afore-mentioned review, to look into the applicability and relevance overseas results to the Hong Kong situation;
- A detailed study on annoyance effects due to transportation noise in Hong Kong, with the help of a household survey and a territory-wide noise mapping conducted respectively by the Census and Statistics Department (C&SD) and the Environmental Protection Department (EPD).

Chapter Two: Methodology

The approach includes a desktop study, a household survey, a noise mapping and the statistical analyses. The household survey was undertaken with the assistance of C&SD and the noise mapping by a third party engaged by EPD separately.

2.1 Desktop study

2.1.1 Literature review

A review on three non-auditory health effects, namely cardiovascular, sleep disturbance and annoyance, due to transportation noise (road traffic, railway, aircraft was undertaken. This review was built upon a pilot study conducted by Wong (2002) suggesting that environmental noise has three strong non-auditory effects: cardiovascular effects, sleep disturbance effects, annoyance effects. The review included the peer-reviewed literature since 2002 and other publications from WHO, EU and the USA.

This review has produced three working papers (Appendices 1-3). Each paper focuses on one of the three non-auditory health effects (cardiovascular, sleep disturbance, annoyance) with respect to transportation noise. A summary of findings of these three papers will be given in subsequent sections.

2.1.2 Previous studies

A few major studies on health effects of noise have been undertaken overseas (e.g. Miedema & Oudshoorn, 2001; Phan et al., 2008; Babisch et al., 2009; WHO, 2011). It is crucial to look into these large studies from overseas in order for Hong Kong to develop her own dataset for comparison with other countries.

2.2 Household survey

A household survey was conducted territory-wide to obtain necessary information on human annoyance and sleep disturbance due to transportation noise of the population of Hong Kong.

Given the professional expertise of Census and Statistics Department (C&SD) on demographic and social surveys in Hong Kong, C&SD was commissioned by EPD to coordinate and conduct the household survey for this study. A field survey provider, MOV Data Collection Centre Limited, was appointed by C&SD to assist with the data collection in the household survey and data preparation.

The household survey was conducted via the periodical thematic social survey undertaken by C&SD in Hong Kong. The household survey related to this particular study was undertaken between 30 November 2009 and 7 February 2010 and was comprised of three themes including this one. Each had a set of questions specific to the theme. There was also a common set of questions, related to the socio-economic background of the respondent. The three themes included “Hong Kong students studying outside Hong Kong” and “Utilization of services provided by managed care organizations” and the current study.

The role of the study team was to design the questionnaire specific to the theme of this study, and in consultation with the Environmental Protection Department (EPD), to provide advice on the formulations of sampling strategy and implementation of the questionnaire survey. The study team also provided trainings to the interviewers undertaking the interview, monitored the survey progress, resolved issues arising from the survey, and oversaw the process of quality assurance and quality check.

2.2.1 Sampling

There are two important issues on the sampling, namely, sampling design and the sample size.

2.2.1.1 Sampling design

One of the key issues is sampling design, which is a difficult issue considering the multiple purposes of the study.

The first purpose is to provide reliable estimates of the percentage of the Hong Kong population who are highly annoyed and sleep disturbed by transportation noise. To achieve this aim, a random sample is preferred and a sample size of several thousand would be adequate to provide estimates with an acceptable error margin.

The other purpose is to elucidate factors which may affect annoyance and sleep disturbance effects of the Hong Kong population with respect to transportation noise. Given the diverse sources of transportation noise and the highly varied human response to noise, a sampling approach targeting specific affected areas (e.g. areas abutting railway lines and under aircraft flight path) is preferred. To ensure that people in different exposure groups are efficiently covered, the sample should also cover areas of low, medium and high exposure groups. This of course requires a-priori knowledge of the spatial distribution of exposure levels of different noise sources in Hong Kong.

Because of the above considerations, it is ideally desirable to have a hybrid approach, combing random and disproportionate stratified sampling covering different noise sources.

However, such a hybrid sampling approach was not possible in this case because the current study was subsumed as part of the thematic survey which, under C&SD, has been using the equal probability approach for conducting household surveys (Appendix 4). Such an approach is akin to random sampling.

There are pros and cons of being part of the thematic survey conducted by C&SD using the equal probability approach. On the positive side, this sampling approach would firstly facilitate collection of data and estimate percentage of the population exposed various types of transportation noise. Furthermore, the thematic survey also provides information on other relevant background information, such as households' socio-economic characteristics of the sampled dwellings. Thirdly, being subsumed under the regular thematic survey, the exact purpose of the survey was masked and the responses given are theoretically less-biased. Finally, the well-established sampling protocols and implementation procedures contributed to the high response rate of 75%.

However, the adopted approach poses limitations. Most important of all, the sample covers the entire territory of Hong Kong regardless whether or not the sampled dwelling is exposed to a particular noise. Hence, the percentage of people highly annoyed with respect to a specific noise may be under-estimated because of the population surveyed includes people who are not exposed to the noise source in question. This problem may be less for road traffic noise because of its prevalence in most parts of Hong Kong and become more prominent with rail and aircraft noise which affect only a small part of Hong Kong. The current study fortunately focuses only on road traffic noise. These issues will be addressed and dealt with in data analysis and interpretation in this report (Appendix 6). Furthermore, given that only a small proportion of the Hong Kong population is exposed to railway noise, a Hong Kong-wide sample is rather ineffective, as compared to a stratified sample, covering only the high, medium and low exposure groups.

2.2.1.2 Sample size

Another key issue in sampling is to determine the size of sample. In order to obtain data with desired reliability on the low, medium and high noise exposure levels and on the health effects of noise, it has to be scientifically rigorous in order to collect sufficient data to obtain statistical power. The need for an adequate sample size was highlighted in previous studies (Miedema & Oudshoorn, 2001; van Kampen et al., 2005)

As part of the thematic study, the sample size was determined by C&SD. Their practice was to select approximately 10,000 households in Hong Kong, a size deemed appropriate for giving reliable figures for policy-making. In this study, a total of 10,077 respondents were successfully interviewed. The sample covered the land-based population aged 18 or above of Hong Kong. The sample did not cover hotel transients, inmates of institutions and persons living on board vessels.

2.2.2 Questionnaire design

2.2.2.1 Construction of questionnaire

The questionnaire of the thematic survey was made up of different components with a common core. For this particular study, it comprises of (a) questions specific to noise constructed by the study team in consultation with EPD; and (b) a core set of questions set by C&SD common to all themes. As indicated above, the purpose of the survey was not disclosed before or during the interview, and the information was obtained with respondents unaware of the purpose of the survey.

The purpose of the noise specific questions was to determine the annoyance reactions of respondents in dwellings with respect to each of the transportation noise commonly found in Hong Kong. Questions in this part were drafted according to the Technical Specification ISO/TS 15666 (2003) and relevant literature (Fields et al., 1997; Fields et al., 2001). These questions were tested in a number of careful steps, including some preliminary try-outs and pilot tests. The latter was undertaken in conjunction with EPD, C&SD and MOV. The views and feedback from the interview team were carefully considered with adjustments to specific wordings to suit the specific situation of Hong Kong. However, those questions stipulated in ISO/TS 15666 document (2003) were strictly adhered to and the interviewers were reminded both verbally and in writing that the ISO wording and protocol must not be changed. Such questions include C4 (annoyance on a 0-10 numeric scale), C7 (annoyance at night on a 0-10 numeric scale), C8 (sleep disturbance on a 0-10 numeric scale)[1] and C13 (annoyance on a 1-5 verbal scale).

The questionnaire also includes other questions which cover a variety of topics which may affect human response to noise. Those questions cover housing environment, perceived physical environmental quality, noise disturbances on activities, coping behavior, noise sensitivity, perceived health and wellbeing. The background and origin of each of these questions are given in subsequent sections.

A. Neighborhood environment

Residential satisfaction is a measure of the contentment of the living environment evaluated by the respondent. It was obtained from a single question on a 5-point Likert-type scale. The responses of the scale included highly satisfied, satisfied, neither satisfied or dissatisfied, dissatisfied and highly dissatisfied.

Information on *Neighborhood characteristics* were obtained by posing two open-ended questions to the respondents who were prompted to name up to three negative and three positive aspects of living in the respondent's estate/ street block.

B. Perceived physical environmental quality

Noise annoyance is defined as an individual's adverse reaction towards noise (ISO/TS 15666, 2003). It is alternatively referred to as dissatisfaction, nuisance, bother, or disturbance due to noise. Noise annoyance was measured by two questions on an 11-point numeric scale – one question asking about annoyance; another one about night time annoyance. The responses of the scale ranged from 0 to 10, where 0 was not at all

[1] The question on sleep disturbance on a 0-10 scale (C8) is not an ISO standard (ISO/TS 15666, 2003), and it is a variation of it.

annoyed, and 10 was extremely annoyed. The responses of 8, 9 and 10 were combined to form a category of “highly annoyed” for analysis.

In order to compare the exposure-response curves (i.e. different noise exposure levels correspond with the percentages of high annoyance of respondents) of various areas or jurisdictions, the 0-10 scale was transformed into a 0-100 scale using the Miedema & Oudshoorn (2001) approach. On the 0-100 scale, 72 was chosen as the cutoff point (Miedema & Oudshoorn, 2001), above which respondents were considered as “highly annoyed”. The percentage of highly annoyed of a community was obtained by summing up the total number of people who are highly annoyed so defined at different exposure levels and divided by the total number of respondents.

Human annoyance reactions were determined with respect to specific noise source, based on which exposure-effect relationships can be established to study human response and for comparison with other areas/countries. In this study, the list of noise sources was compiled from those suggested in the ISO/TS 15666 (2003) document and having regard to the specific situation of Hong Kong. Noise sources suggested by ISO/TS 15666 (2003) included road traffic, trains, aircraft, factories or machinery, construction work, animals outside, children outside and people outside. Considering the local environment of Hong Kong, a few specific noise sources were added or modified. Firstly, trains were defined as MTR, trains or LRT. Secondly, factories or machinery were changed to industries/ factories/ machineries. Thirdly, construction work was elaborated as construction/ demolition. Fourthly, noise from “children outside and people outside” (ISO/TS 15666, 2003) was not used. Fifthly, several noise sources were added to the list: commercial activities, renovation, neighbor’s air conditioning, neighbors, playgrounds/ sportsground. Following these amendments/elaboration, the noise sources in the annoyance questions now include: road traffic, MTR/ trains/ LRT, aircraft, industries/factories/machineries, commercial activities, construction/ demolition, renovation, neighbor’s air conditioning, neighbors, playgrounds/ sports ground and animals outside.

In addition to the 0-10 numeric scale for noise annoyance measurement, a 1-5 verbal scale was also adopted (ISO/TS 15666, 2003) as a counter-checking question to examine the consistency of the noise annoyance response in comparison with the 11-point numeric scale. According to the on the 1-5 scale, the verbal labels are as follow: not at all annoyed, slightly annoyed, moderately annoyed, very annoyed and extremely annoyed.

C. Disturbances and coping behavior

A 4-point scale of noise disturbance of human activity was constructed to provide information on disturbances on telephone conversation, normal conversation, listening to television or radio, rest and relaxation and concentration on tasks. The responses on the 4-point scale included never disturbed, sometimes disturbed, a lot disturbed and nearly all the time disturbed.

Sleep disturbance, in particular, was measured by using the same 0-10 numeric scale and noise sources as annoyance aforementioned.

Sleep quality was assessed by using a scale, called Groninger sleep quality scale (Meijman et al., 1985). It was developed in the 1980s aiming to measure the subjective sleep quality in relation to objective sleep indicators. Later this scale was applied and adjusted in several noise studies in the Netherlands. This scale consisted of twelve statements with dichotomous response of either yes or no. Each statement represents an aspect of sleep quality, according to the so called Mokken model[2]. The scores of each statement were summed up, indicating that a higher score represented a lower quality of sleep. An advantage of using the Groninger sleep quality scale is that it does not imply sleep disturbance due to noise, meaning that the relationship between noise and sleep could be studied in a non-contaminated manner.

Coping was measured using a limited set of behaviors which people can undertake to reduce external noise or its negative effects. Two questions were used pertaining to coping: switching on the air-conditioner and closing the windows, which are considered as coping strategies applicable in Hong Kong. This information is considered to be useful to indicate what strategies Hong Kong people use to reduce the negative impact of environmental noise. It was noted that the coping behaviors included in this study are very limited, and that more potential coping strategies could be used in future analysis (e.g. use of tranquilizers, alcohol to improve sleep, earplugs, send a complaint, relocation, etc.). However, the constraint on the length of the questionnaire precluded inclusion of more in-depth questions.

Noise sensitivity is defined as the internal state (physiological, psychological, attitudinal, lifestyle, or activities) of an individual that increases one's degree of reactivity to noise in general (Job, 1999). It is a key factor in predicting annoyance of noise. Noise sensitivity was assessed making use of a revised and short version of the Weinstein (1978) scale, which was developed and tested by Kishikawa et al. (2006) and tested by Matsuyi (Kishikawa et al., 2009). This so called WNS_6 scale includes 6 items with responses to a 6-point scale ranging from 0 (strongly disagree) to 5 (strongly agree). The scores were then summed up and recoded into a tertile scale (van Kamp et al., 2004). The reason for recoding into a tertile is that there is no threshold or norm value available above which is considered highly sensitive, and so the tertile scale was used to represent the low, medium and high levels of sensitivity to noise.

D. Perceived health and wellbeing

The questions concerning perceived health and wellbeing address people's perceived quality of life, general health status (Fukuhara et al., 1998), chronic physical disorders,

[2] Mokken Model: Mokken scale analysis (MSA) is a scaling procedure for both dichotomous and polytomous items. It consists of an item selection algorithm to partition a set of items into Mokken scales and several methods to check the assumptions of two nonparametric item response theory models: the monotone homogeneity model and the double monotonicity model.

chronic mental disorders, use of medication and hearing problem. Since these health-related questions *per se* do not have a direct relation to noise, these health effects can be included as confounders, but also as endpoints, such as in the relation to annoyance and sleep disturbance.

E. Life style of respondents living in the estate/ street block and others

A series of life style questions about the respondents living in the estate/ street block were asked to help finding out the confounding factors of the health responses of transportation noise. The types of questions included: waking and sleeping times, perceived satisfaction with number of hours of sleep, shift work pattern, residence duration, frequency of sleeping with windows closed, frequency of keeping the windows closed during the day, number of rooms in the household, access to a quiet room (room not facing roadway or railway), etc.

Common questions

This study also made use of a set of core questions common to all themes in the survey. They were set by C&SD with the purpose to obtain the demographic features and socio-economic characteristics of respondents corresponding to that household. Such information is needed to assist data analysis and interpretation.

The types of common questions include living quarter information, household information such as ownership and number of household member, household member information such as gender and age, personal data such as marital status, education, employment, industry, occupation, monthly personal income and monthly household income.

2.2.2.2 The questionnaire

Given the above considerations, the final questionnaire is comprised of the following components.

a) Noise-related questions

- Neighborhood environment
    - Satisfaction of living in this estate/ street block
    - Three negative aspects of living in this estate/ street block
    - Three positive aspects of living in this estate/ street block

- Perceived physical environmental quality
    - **ISO/TS 15666 (2003) question: annoyance on a 0-10 numeric scale**
    - **ISO/TS 15666 (2003) question: annoyance at night on a 0-10 numeric scale**
    - **ISO/TS 15666 (2003) question: annoyance on a 1-5 verbal scale**

- Any other noise source from outside home that bother, disturb or annoy the respondent

- Disturbance and coping behavior
  - Disturbance of action from external noise
  - Coping behavior against external noise
  - **ISO/TS 15666 (2003) question: sleep disturbance on a 0-10 numeric scale**
  - Sleep quality
  - Noise sensitivity
  - Measures taken to reduce external noise

- Perceived health and wellbeing
  - General health status
  - General health status as compared with that one year ago
  - Whether consulted a general practitioner (GP) or local doctor about health in last two weeks
  - Whether been hospitalized in the last two years
  - Whether been diagnosed by a doctor with the following diseases:
    - Hypertension
    - Heart disease/ cardiovascular effects
    - Diabetes
    - Chronic headaches/ migraines
    - Depression/ anxiety
    - Insomnia (severe sleeping problems)
    - Peptic ulcer
    - Asthma
  - Whether been treated regularly for the diseases mentioned above
  - Whether taken the following drugs in the last one month:
    - Hypertension drugs
    - Cardiovascular drugs
    - Anti-diabetic drugs
    - Sleeping pills
    - Tranquilizer
  - Frequency of taking the type of drug mentioned above
  - Whether have hearing problems or difficulties without using hearing aid
  - Conditions of hearing problems or difficulties
  - Whether hearing aid is needed

- Habits of respondents living in the estate/ street block and others
  - Getting up time and going to bed time
  - Desired hours of sleep
  - Employment status as a leading question to the shift work questions
    - Whether require overnight shift work

        - Whether frequently work overnight shift or work day and night alternative shift
    - Year of residence
    - Number of rooms in the household
    - Time being at home
    - Frequency of sleeping with windows closed
    - Frequency of closing windows during day time
    - Whether have air-conditioner in the living room/ dining room
    - Whether have air-conditioner in the bedroom
    - Whether have one or more bedrooms NOT facing roads or railways (quiet room)

b) Common questions

- Living quarters information
    - Type of living quarters (public/ private)
    - Floor level of living quarters
    - Number of households in the living quarters

- Household information
    - Whether rent or own this house/ flat
    - Number of household members
    - Relationship of household members with respondent

- Household member information
    - Gender
    - Age
    - Total amount of time spent in Hong Kong in the last six months
    - Total amount of time to be spent in Hong Kong in the coming six months
    - Whether a Hong Kong permanent resident
- Personal data
    - Marital status
    - Whether being a full time student
    - Level of education
    - Whether a one-way permit holder coming from the Mainland to reside in Hong Kong
    - Whether have a full time job
    - Industry
    - Occupation
    - Whether activity seeking work
    - Income sources
    - Monthly personal income
    - Monthly household income

2.2.2.3 Language and wordings of questionnaire

a) Development of Cantonese wordings for ISO questions

Hong Kong is predominantly a Cantonese-speaking area; however, there is no direct correspondence between the written Chinese and colloquial Cantonese for the noise-health survey. Hence, it is important to carefully develop a Cantonese questionnaire for the study such that the meaning is not distorted and the findings can be used for cross-cultural and international comparison.

The fundamental reference is the ISO/TS 15666 (2003) document and the closest Chinese language questionnaire developed is the one in Mandarin (Ma et al., 2003; Yano & Ma, 2004). However, there are differences between the Cantonese and Mandarin language and the latter was used as a reference to start in Hong Kong.

Following the initial translation, a trial study (Appendix 5) was carried out using Ma et al. (2003)'s approach with the aim to (i) find out five Cantonese modifiers which best describe the response levels of noise on the 1-5 verbal scale and correspond to the English's standardizations, namely "Not at all", "Slightly", "Moderately", "Very" and "Extremely"; (ii) apply these five Cantonese modifiers into the ISO questions including 1-5 verbal scale on annoyance, 0-10 numeric scale on annoyance at night, 0-10 numeric scale on sleep disturbance; (iii) with the application of the Cantonese modifiers, test if the respondents understood the questions and were able to respond to the questions; (iv) try out the Show Card of the ISO questions.

Based on the results of the trial study, five Cantonese modifiers were identified to be "完全唔 (嘈)" (Not at all), "有 D (嘈)" (Slightly), "(嘈)" (Moderately), "好 (嘈)" (Very) and "極之 (嘈)" (Extremely). With the application of the Cantonese modifiers into the ISO questions, the results showed that respondents clearly understood the questions with the Show Cards; and were able to distinguish and choose between the five selected Cantonese modifiers which best described their situations.

With inputs from C&SD and MOV, the study team also translated other parts of the noise questionnaire into Cantonese. They were also subsequently tested by the interview team.

b) Other languages for the questionnaire related to noise

In addition to Cantonese, the English and Mandarin Chinese versions of the noise questionnaire were also developed and used accordingly in the survey.

2.2.3 Pilot studies

In order to test the applicability of the questionnaire and the fieldwork procedure, a pilot study was conducted during 5-8 November 2009 in a sample of 100 dwellings randomly selected territory-wide.

To ensure that the interview was conducted in strict compliance to ISO/TS 15666 (2003), the study team highlighted the importance of the ISO requirements to EPD, C&SD and MOV and briefed the interviewers before and after the pilot study. The meetings helped resolved issues arising from the pilot study. The study team also provided training sessions to the interviewers specifically on the wording and precautions of the noise questionnaire.

The pilot study identified a small number of issues related to specific wordings which might be unclear to the respondents. Corresponding amendments were subsequently made to address issues raised. Also, a coding scheme for open-ended questions were suggested and finalized.

2.2.4 Conducting the household survey

The household survey was conducted between 30 November 2009 and 7 February 2010. A total of 10,077 households were successfully interviewed, giving a response rate of 75%.

According to the protocol of C&SD, the main procedures of conducting the household survey were as follows:

- A letter was sent by C&SD to selected households informing that an interviewer was to conduct a face-to-face interview with the household for a survey.
- During the period of interview, if the interviewer was not able to contact the household, the interviewer might try again for three times, after which if the same situation remained; another household would be randomly sampled for replacement.
- If the household refused to be interviewed, or if the case was decided invalid, the case would be followed up by the interview supervisor before the case was discarded.
- If the household agreed to the interview, a member of the household would be selected randomly from among all members for the survey.

2.2.5 Validation and quality check

A number of measures were taken to ensure that the survey results were reliable. Firstly, an independent check of about 15% of the completed questionnaires was performed by MOV as per the specification of C&SD. Selected household would be asked a few questions. The answers given in the original and follow-up interviews were then compared and dubious cases discarded. Secondly, a double data entry system was adopted for inputting data into the computer in order to minimize typing errors. Thirdly, acceptance tests on data were performed by MOV for various computer processing systems. Finally, some data screening and consistency checked were undertaken by the study team using SPSS.

2.3 Noise exposure estimation

The noise exposure of households selected for interview was determined by noise mapping, as a separate job, by a service provider engaged by the Environmental Protection Department. It is understood that the noise mapping was done using the noise prediction software LIMA and supplementary digital topographic, buildings and traffic data for the year 2010 obtained from relevant government departments. For privacy reasons, the addresses of dwellings selected for the interview and noise mapping were not known to the study team. The matching of interview and noise mapping addresses were undertaken by EPD. The noise exposure of a total of 10,077 dwellings, selected by C&SD for the interview was estimated. The noise exposure estimates covered living quarters in the whole territory of Hong Kong, irrespective of whether the households were in the city or countryside, urban or rural areas of Hong Kong, and exposed whether or not to a particular noise source.

Theoretically, noise mapping can cover all sources of transportation noise in Hong Kong – road traffic, rail and aircraft. However, the feasibility depends on the availability of road, rail and air traffic data. The current study focuses on road traffic noise provided by EPD. As indicated in Section 2.2.2, the questionnaire was designed in such a way that human response to transportation noise is source specific. In other words, the questionnaire data are capable of handling human response to multiple sources. Hence, additional analysis can be undertaken if and when noise exposures other than road traffic are available.

The technique of noise mapping has been developed for over a decade and implemented in a number of countries, particularly in Europe where member countries are obliged to do noise mapping for urban agglomerations under an EU Directive (Council Directive 2002/49/EC, 2002). In recent years, there have been studies looking into the accuracy and uncertainty of different prediction methodologies.

For the current study, both the CRTN and ISO 9613 methodologies were used. For several decades, CRTN has been adopted in Hong Kong as the standard methodology to estimate road traffic noise ($L_{10,\ 1h,\ peak\ h}$). The same has been used in the U.K. to estimate $L_{10,\ 18h.}$ The relationship between various L10 metrics has been determined for Hong Kong (Lee et al., 2003).

Unlike the CRTN model which yields noise estimates based on L_{10}, more and more countries have switched to L_{eq} which is based on energy equivalence. The use of L_{eq} also allows estimation of time-based noise metric such as L_{DEN}, $L_{EVENING}$ and L_{NIGHT}. All these estimates can be obtained using the ISO 9613 propagation model and related traffic flow data. The use of L_{eq} facilitates comparison with other countries such as UK, U.S.A., Japan and Australia and China.

In this study, noise exposure estimates based on the following metrics have been provided to the study team for analysis:

- CRTN Method: $L_{10,\ 1h,\ a.m.}$; $L_{10,\ 1h,\ p.m.}$
- ISO 9613 Method: L_{DEN} , L_{DAY}, $L_{EVENING}$ and L_{NIGHT}

The exact location for noise exposure prediction for each dwelling was determined at a point 1 m at the most exposed facade of the dwelling. While the accuracy of the prediction methodologies used is not the subject of this study, it is known that the error margin of the CRTN method has been assessed in Hong Kong and found to be acceptable. Some recent studies have also looked into the accuracy and uncertainty of various prediction methodologies in noise mapping (Shilton, 2010). It was reported that the CRTN method provides a relatively larger spread of the error but the smallest average difference between actual and predicted values (Shilton,. 2010). Cho et al. (2004) used the ISO 9613 method and reported an overall error of 0.3 dB with a standard deviation of 2.05 dB.

In using the above noise prediction methodology for Hong Kong, it is worthwhile to note that the accuracy is significantly compromised at the low exposure end. This is because while traffic flow data are generally available for heavily trafficked roadways; very few flow measurements have been made for minor roads and side streets. In the absence of traffic data, some simple estimates have to be made based on simple assumptions.

2.4 Exposure-effect curve

The exposure-effect curves of Hong Kong on annoyance and sleep disturbance to road traffic noise was developed using the approach of Miedema & Oudshoorn (2001) and Miedema et al. (2002). Those curves can be used to compare the response of the Hong Kong population with those in overseas countries (Miedema & Oudshoorn, 2001; Phan et al., 2008; Phan et al., 2010).

For the construction of the exposure-effect curve of Hong Kong, the ***Percentage of Highly Annoyed*** (%HA) and the ***Percentage of Highly Sleep Disturbed*** (%HSD) on a 0-10 numeric scale for road traffic noise respectively are defined as partial 7, 8, 9 and 10 as per Miedema & Oudshoorn (2001).

Two noise exposure metrics, L_{DEN} and L_{NIGHT}, were used to correlate with annoyance and sleep disturbance respectively.

In Miedema & Oudshoorn (2001) analysis, extreme exposure levels were excluded from the analysis to minimize the risk of including unreliable data at high and low ends (Miedema & Oudshoorn, 2001). They suggested discarding cases with noise exposure estimates falling beyond the ranges of L_{DEN} 45-75 dB for annoyance and L_{NIGHT} 45-65 dB for sleep disturbance.

Exposure-effect curves are built on regressions models. To choose the curve of best fit, different regression models (linear, 2nd and 3rd polynomial) were tried for each data set and the model was selected based on the R^2. It was found that the R^2 in the 3rd order polynomial function was highest among all, and thus the 3rd order polynomial function, also adopted by Miedema and Oudshoorn (2001), was used to construct the exposure-effect curve for this study.

2.5 Statistical analysis

2.5.1 Tabulations of individual responses and composite scores

It should be noted that individual responses of some questions are not meant to be taken and interpreted individually. Examples include questions on annoyance or sleep disturbance response on the 0 to 10 scale. Those questions are designed to obtain the respondent's level of annoyance or sleep disturbance in accordance with ISO/TS 15666 (2003). The 0 to 10 scale are constructed to determine whether the respondent is "highly annoyed" or "highly sleep disturbed". Individual responses are not meant to be interpreted separately (e.g. % of people not bothered at all by a specific noise source).

Furthermore, there are a few questions (sleep quality (C9) and noise sensitivity (C12)) which are posed as several separate questions to the respondents. They are in fact, different dimensions of the same questions, the response of which are used to build composite scores. Accordingly, the response to individual questions should not be tabulated and interpreted separately.

2.5.2 Frequency tabulations and plots

For most of the remaining variables, the study has tabulated the responses and frequency tables and distribution curves to provide some preliminary analysis of the data.

2.5.3 Comparison of exposure-effect curves

To compare the response of the Hong Kong population with respect to a specific noise source with that of other countries, it is customary to compare the slope and intercept of the regression relating noise effects to exposure by the analysis of co-variance. However, such a comparison can only be undertaken if the confidence intervals of the curves are known. Unfortunately, such data are not given in most previous studies. In the absence of such data, whether or not one curve is significantly different from the other cannot be ascertained.

However, if the confidence interval is portrayed graphically even if the relevant statistics are not given (Miedema & Oudshoorn, 2001), this report will show the confidence interval of the curves graphically to give a rough assessment whether or not the curves are likely to be different.

2.5.4 Binary logistic ordinal regression

It is one of the objectives of the study to elucidate factors, acoustic or not, which may make one feel “highly annoyed” or “highly sleep disturbed”. Regression analysis is used to find out how important noise exposure is; and then to determine what other confounders may moderate or enhance the feeling of annoyance and sleep disturbance. Details of the analysis are given below.

- Regression model:
    - Binary logistic ordinal regression analysis

- Method of binary logistic ordinal regression analysis:
    - Most independent variables are in interval scales (continuous) (Table 6.5). The criterion for including or excluding a variable is set at 0.05 significance level.
    - These independent variables are entered in block by block using stepwise approach.
    - We focus on looking at the **odds ratio** in the output. A ratio smaller than 1 indicates that the factor moderates annoyance. On the other hand, a ratio greater than 1 indicates that the factor accentuates annoyance.
    - We also look at Nagelkerke R square which is a descriptive measure of the explanatory power of the selected variables.

- Dependent variable:
    - Whether or not the respondent is “highly annoyed” (8, 9, 10 on the 0-10 scale). It is in binary form (0 = no; 1 = yes);
    - Whether or not the respondent is “highly sleep disturbed” (8, 9, 10 on the 0-10 scale). It is in binary form (0 = no; 1 = yes).

- Independent variable:
    - Block 1: Noise exposure
        - 24h, i.e. throughout the day (L_{DEN}); at night (L_{NIGHT})
    - Block 2: Physical factors affecting noise exposure
        - Access to quiet room; closing windows; crowdedness; number of households in the living quarters
    - Block 3: Personal factors affecting perception
        - Satisfaction with neighborhood environment; ownership; quarter type; length of residence
    - Block 4: Other personal factors
        - Noise sensitivity; health status; hearing problems; poverty; gender; age; employment; shift-worker; education level; occupation; monthly household income; sleep outside curfew; sleep deprivation

Chapter Three: Summary of scientific understanding of the effects of transportation noise on annoyance, sleep disturbance and cardiovascular diseases

This study comprises of three separate in-depth review of the effects of transportation noise on three key aspects of human health. The findings have already been presented to EPD in the form of Working Papers (Appendices 1-3) where details can be found. The following provides a gist of the major findings.

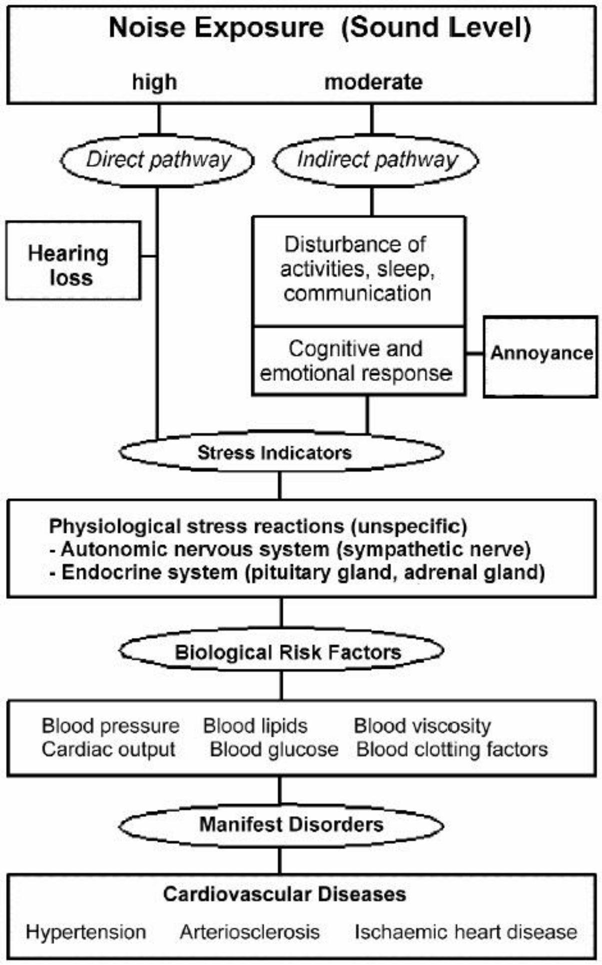

Figure 3.1: Noise effects reaction schema (Source: Babisch, 2002)

3.1 Annoyance effects with transportation noise

Annoyance is one non-auditory health endpoint (or health outcome) of interest related to human exposure to environmental noise (Figure 3.1). Noise annoyance is a feeling of resentment, displeasure, discomfort, dissatisfaction, or offense when noise interferes with someone's thoughts, feelings, or actual activities.

Public health experts agree (though not universally) that high levels of noise-related annoyance should be considered a legitimate environmental health issue affecting the wellbeing and quality of life of the population exposed to environmental noise (Health Protection Agency, 2009),

Environmental Noise Directive (END) in Europe (Council Directive 2002/49/EC, 2002) recommends evaluating environmental noise exposures on the basis of estimated noise annoyance, in addition to evaluation on the basis of estimated sleep disturbance.

While it is not yet possible to predict noise annoyance on an individual basis because of the large variety of (partly unknown) endogeneous and exogeneous characteristics that affect annoyance, the relationships between noise annoyance and noise exposure have been elucidated on a population level together with several effect-modifying factors.

Babisch et al. (2003) reported evidence that noise annoyance due to exposure to road traffic may be a risk factor for the incidence of ischaemic heart disease, with pre-existing chronic diseases modifying this association, though there is no consensus on this as yet.

Under a stress model of the effects of noise, noise annoyance by itself is an adverse outcome of exposure to noise as well as a contributor to those further effects (or an indicator that further effects may occur). However there is limited evidence, and no consensus, that increased annoyance response is an intermediary in the noise exposure/ physiological response pathway.

People may reduce the negative impacts of their environmental stressors (noise) by coping strategies. Active coping is generally considered as the most effective strategy that people can adopt, and avoidance the least effective (van Kamp, 1990). However, environmental exposures are often outside the control of people and even though active coping leads to reduced stress feelings, and annoyance, it can, in the long term, lead to increased risk of hypertension (van Kamp, 1990). This is a consequence of the environmental factor lying outside the control of the individual, which in itself can enhance stress and lead to long-term health problems.

Standardized procedures (ISO/TS 15666: 2003) are available for questionnaire assessment of annoyance, and these should be used in all Hong Kong studies of annoyance.

The noise metrics (or noise indicators, or noise scales) adopted to assess and manage transportation noise immission – that is, noise immission primarily to dwellings – still varies considerably from country to country. However the adoption and continued use of the different noise metrics depends as much on the inertia of regulations, standards and current practice as it does on current scientific evidence.

In making a choice of any particular noise metric there are two matters that should be considered. Firstly, the metric should correlate with annoyance within the population of interest (or the metric should correlate with annoyance in a synthesis of studies from elsewhere). Secondly, provided the first condition is met, there are benefits in harmonizing the noise metric with other countries in terms of being able to compare population exposures and limit values, and to utilize prediction models and other tools that are developed elsewhere.

The European Union has adopted specific noise metrics on this basis across all member countries. While noise limits are set by EU Member States, the harmonized noise metrics are L_{DEN}, to assess annoyance, and L_{NIGHT}, to assess sleep disturbance. These metrics are common across all transport sources, and other sources of environmental noise.

The issue of noise events in the traffic stream as a determinant of *annoyance* is still unresolved.

Extensive meta-analyses have lead to the production of several different exposure-response relationships between annoyance and transportation noise exposure.

The EC working group on health effects of environmental noise recommended (European Communities, 2002) the relationships presented by Miedema and Oudshoorn (2001) for estimating noise annoyance based on the external noise exposure of dwellings – with different curves for aircraft, train and road traffic.

However, other exposure-response curves for annoyance from transport noise:

- The revised international standard ISO 1996 – Part 1 (2003). The standard has a table for source dependent corrections. Aircraft noise levels are corrected as “3 to 6 dB” relative to road traffic noise and the railroad bonus is also defined as “3 to 6 dB”.
- The American standard ANSI 12.9 – Part 4 (2003) specifies yet another dose-response function. This standard uses the same function as ISO 1996, but the correction factors are different. There is no railroad bonus, and the aircraft noise penalty varies between “0 dB” and “5 dB”.

The generalizability of such derived exposure-effect curves to different countries and different areas has not been well established. Issues that are relevant for Hong Kong (and elsewhere) are that:

- Prediction of the fraction of people highly annoyed based on an estimate of exposure may differ considerably from the outcome of a specific survey of annoyance in an exposed population (Passchier-Vermeer and Passchier, 2005).
- Most exposure-response studies included in the synthesised curves are from Europe, North America and Australia, and there have been few studies from Asia, or from areas with high residential densities, high road traffic densities, or different urban forms, such exist in Hong Kong, or that have gone through rapid periods of economic growth and urbanisation.
- There is debate over the appropriateness of a “railway bonus” – response in Japan to road traffic and conventional rail traffic was the same.

- The generalized curves have been based on data several decades old and therefore may not represent current conditions. The UK Health Protection Agency (2009) suggests that there is accumulating evidence that attitudes and opinions to noise may have been changing significantly over the past twenty or thirty years (increasing annoyance at the same exposure). This is an issue of current concern and debate, but not one on which there is agreement as to the explanation.

Step changes in transport noise exposure occur in range of practical situations such as where new roads and railways are constructed or existing ones closed or there are major increases or decreases in road, rail or air traffic. There is evidence that, when exposure changes, people respond very differently than is anticipated by steady-state exposure response curves. Brown and van Kamp (2009a, 2009b) provide evidence of the existence of a change effect.

The approach to calculating the environmental burden of disease to transportation noise has been described.

The role of soundscape in annoyance outcomes from noise exposure has been briefly examined. They include restorative capacities of soundscapes on human health and well-being and the value of high quality acoustic environments to people otherwise living in noisy urban environments, and some evidence that a "quiet side of building" may reduce annoyance from otherwise high exposure to transport noise.

3.2 Sleep disturbance effects with transportation noise

Sleep is a biological necessity, and disturbed sleep is associated with a number of adverse impacts on health. Sleep is also an essential part of human functioning and is recognized as a fundamental right under the European Convention on Human Rights (Article 8.1). Sleep disturbance can thus be considered as one of the main aversive effects of night time exposure to transport noise and protection against this can only be achieved by setting limit values for night time noise levels on top of the existing policies which are primarily based on day time levels and noise annoyance.

There is sufficient evidence that night time transport noise leads to acute effects such as physiological response, arousal, awakening, sleep stage changes, and the amount of total sleep. It also leads to after effects such as self-reported sleep disturbance, reduced performance in the day time and cognitive effects. However, what the long term health effects at cognitive, physiological, emotional and behavioral level (performance) are of these instantaneous and short term effects of noise on sleep, is still unclear and hypothetical. Habituation was found in several laboratory studies but, due to unrealistic noise exposure characterization, these findings might not be applicable to real life situations. This might indicate that the time interval between two noise events also has an important influence on the probability of obtaining a response. Moreover, evidence on habituation is restricted to awakenings but not available for physiological, perceived quality and other after effects. The autonomic responses do not habituate. We still lack evidence regarding the long term effects of instantaneous sleep-disturbances but more recently there is evidence of increased risk of diabetes due to sleep disturbance (Donga et al, 2010).

According to the WHO, there is nevertheless consensus about the biological plausibility that short term sleep disturbances form a long term health risk. There is sufficient evidence that chronic sleep disturbance is related to self-reported overall sleep disturbance, insomnia-like symptoms, as well as increased medication use. For cardiovascular disease (CVD) and depression, among others, no such relation can be established based on current evidence. However, in particular night time noise exposure is considered to be a risk factor for cardiovascular disease (see e.g. HCN, 2004; Maschke & Hecht, 2004).

In general it has been found that laboratory studies and field studies produce divergent results, and this appears to be related to aspects of habituation or aspects of the noise exposure itself. There is also a systematic difference between results on subjective and objective outcomes, which sometimes seem to be contradictory, but there is growing insight that these have to be considered as separate aspects of the sleeping process. Subjective responses have been found to habituate, whereas physiological responses do not show adaptation. So even if an individual does not report subjective disturbance of the sleep or night time noise annoyance, this does not exclude that the individual is experiencing physiological reactions. These persistent physiological responses to night time noise might have more detrimental effects in the long term than subjective effects, although chronic subjective sleep disturbance might, via stress processes, lead to more serious health problems in their own right.

There has been an ongoing debate regarding the appropriate noise metric to be used to assess sleep disturbance. From current evidence it is clear that different indicators of sleep disturbance are related to different noise metrics and a combination of L_{Aeq}, L_{max} and SEL is preferable. An association between L_{Aeq} and L_{NIGHT} has been established for subjective sleep disturbance, motility and awakenings, whereas single event levels, L_{max} and the number of events (combined with levels) are more predictive of instantaneous and short term effects of arousal, cardiovascular responses and sleep stage shifts, to name a few.

Current evidence has shown that some effects are not a “real” noise effect but a by-product of sleep stage shifts, as is the case for performance related cognitive effects, or blood pressure and heart rate responses. The latter have been found to be an effect of awakenings rather than a direct noise effect.

Although recent studies have considerably increased insight into the mechanisms that play a role in noise sleep effects, the step from these findings to assessing impact at the population level, and defining the key information needed to derive these impacts, is still a tenuous one.
Despite these uncertainties, current policies and guidelines, as published by the EC Commission and the World Health Organisation, have suggested standards for the noise metrics for sleep disturbance, the sleep effects to consider, the dose response relationships to apply and the threshold levels to be used in preparing night time noise policies. Threshold levels, L_{NIGHT}, outdoors have been proposed ranging from:

- 30 dB(A) or below: no effect,
- 30-40 dB(A): some effects, but within acceptable limits, except for vulnerable groups,
- 40-50 dB(A): where the effects are considerably increased and for vulnerable groups one could speak of severe effects, and
- Over 55 dB(A): where one could speak of a serious public health problem, with potential cardiovascular risk.

There is no evidence as to whether the limits are applicable to other countries, and specifically to Asia[3]. Studies from Asia are scarce and studies which have been reported (e.g. from Korea or Japan) were strongly epidemiologically oriented. However there is no reason to assume racial or cultural differences in adaptation of reactions like awakenings, motility and cardiovascular reactions during sleep. A clear distinction is therefore be made between annoyance during night and other, more objective sleep indicators. The Night Noise Guidelines (NNGL, 2009) has only recently been published and their adoption is still being considered. WHO recognizes that these limit values might not be realistic to achieve in many places in the world, when noise levels are considerably higher and has therefore formulated interim target value of 55 dB (L_{NIGHT}, outdoor).

The various dose response relations were primarily derived from EU and USA studies. Differences not only could include factors such as background noise levels and housing differences, but also social differences (e.g. cultural differences in noise sensitivity, or in sleeping patterns in terms of duration of hours being asleep).

From the current literature, several of these so called non-acoustic factors have been studied, but not in a systematic way, and the evidence often remains anecdotal and highly dependent on the particular composition of the population being studied. In laboratory studies these aspects are controlled, but at the price of ecological validity.

It is in this realm that the studies performed in the past eight years, combining field and laboratory approaches and including larger sample size and more heterogeneous groups of participants in their normal living environment, have made the largest contribution.

Vulnerable groups identified in the literature include the: elderly, children, shift workers, pregnant women, people with a sleeping disorder, and the chronically ill—each with their specific risk factors. For example, it has been shown that shift workers have effects across all noise levels. Children score better on awakening and subjective sleep disturbance but show a higher level of motility than adults. Since they are in a vulnerable period with regards to

[3] The NNGL are based on international evidence but includes few studies from Asia. The NNGL might indeed not be feasible in Hong Kong but it is still not expected that objective sleep responses might be very different across cultures. Regarding subjective reactions this might be true indeed. There is a dilemma here: while objective measures are better indicators for sleep disturbance the evidence is primarily on acute effects, while it is not known yet what the long term effects are. On the other hand subjective sleep disturbance is such a chronic effect (which is well related to L_{NIGHT}) but this effect seems to habituate and it is unknown whether these effects are culture sensitive.

development and learning, the effects, at a cognitive level, of a disturbed sleep such as sleep stage shifts, might be much larger in children than in the case for adults.

Summing up these new findings and in view of the limitations of the evidence of noise induced sleep disturbance until 2002, it can be concluded that the noise and sleep field has definitely progressed but as shown above, there is still ongoing debate on what effects need to be taken into account when applying these findings at a population level, which threshold levels should be used, and which generalized exposure response relationships should be used. Another limitation of particular importance in the context of this working paper is the primarily Western Europe orientation of sleep research and thus the limited base of these findings. However, sleep researchers are of the opinion that the basic physiology of sleep, and sleep disturbance by noise, may not be different across cultures. A large cross-cultural study, which would apply the same methods in different parts of the world, would be necessary to fill in this knowledge gap. This also applies to the specific situation in Hong Kong with higher densities and primarily high rise buildings. A first step in that direction would be to estimate the number of people affected by transport noise in Hong Kong in terms of sleep disturbance by means of a Health Impact Assessment (HIA). For such an exercise to be valuable, more information about the Hong Kong conditions, in terms of, for instance, car fleet, types of rail system, proximity to major airports, noise load and number of people exposed to different levels, housing stock, demographics and sleeping patterns, would be essential.

Noise policies in Hong Kong are currently based on annoyance. This does not necessarily protect sleep and additional limit values for night time noise, in line with WHO, are recommended. The WHO target values for night time noise might be a good instrument for this. Although L_{max} and SEL are important noise indices in relation to acute noise effects during sleep, L_{DEN} and L_{NIGHT} are proposed as suitable noise metrics, providing a considerable degree of protection against noise during sleep, in line with the current recommendations of the European Commission, The Health Council Netherlands and the WHO. L_{NIGHT} level ties the L_{Amax}-related effects to a maximum and therefore allows for a protective/ conservative approach. Subjective sleep disturbance is hereby a suitable indicator and possibly being more predictive of long term effects than instantaneous effects as arousals and motility. The planned survey in Hong Kong will provide important data for this, including data regarding subjective sleep quality, sleep disturbance per source and sleep annoyance during the night as well as important demographics and confounding factors. The application of the Night Noise Guidelines for Hong Kong is a matter of consideration of the relevant authorities. From the Hong Kong survey both self-reported sleep disturbance and night time annoyance will be available as well as a scale regarding sleeping quality and medication use regarding sleep. Especially the latter will shed more light on the extent of the problem in Hong Kong. If we have the noise data available we can check if there are major deviations of the dose response curves which are available from international studies. Noise policies and limit values are economic and political decisions which are beyond the scope of this scientific review. WHO recognizes that there are practical limits in implementing the guidelines

Large and longitudinal epidemiological studies with representative sample are seen as necessary to further the field regarding the association between night time (aircraft) noise exposure and cardiovascular disease/ long term health effects.

3.3 Cardiovascular effects with transportation noise

A large number of studies, published between 1980 and 2009, were reviewed on environmental noise and cardiovascular diseases. While some studies reported fairly consistent findings, others gave insignificant or even contradictory results. Consistency of findings is one of the criteria (though not a 'necessary' criterion) for causation in the determination of a cause-effect relationship, as advocated by Hill (1965). Hence, similar results reported by a large number of studies are regarded as being more credible than that reported in a single study. On the contrary, contradictory findings can be interpreted as the absence of consensus in the scientific community. These can arise when the effect size of the risk factor under study is small. A risk factor with a small relative risk (RR) or odd ratio (OR) is easily influenced by confounding factors, especially when there are multiple confounding factors that are difficult to identify and control for. Statistically insignificant results can arise when the sample size of the study is too small, or the effect size is too small, or both. The proper interpretation of an insignificant result is that the observed results can be a chance finding. Care must be given in the interpretation of a scientific paper. Besides noting the magnitude of the relative risk, odd ratio or other risk estimates and their statistically significance at specified levels, other issues in the study design, such as biases in sample selection and ascertainment of 'exposure' and 'effects' must be critically examined. Potential confounding factors must be identified and controlled for, to reduce the likelihood of making an erroneous conclusion.

Environmental noise, whether from transport, industry, or neighbors, has been extensively studied with respect to its effect on cardiovascular health. While acute exposure to noise results in physiological responses, it is uncertain whether such effects are associated with the long-term risk of cardiovascular diseases.

The magnitude of the difference in blood pressure between those exposed to noise and the control group is small and of little clinical significance. Whether hypertension will be a consequence of noise exposure in childhood is still unknown. Adult hypertension might be linked to aircraft noise, as evidenced by a recent cohort study (Eriksson et al., 2007). Evidence for a link between hypertension and road traffic noise has increased from recent studies. Earlier inconsistencies might well be explained by bias, or by inadequate adjustment for confounding factors.

The link between ischaemic heart disease and noise is less convincing, with statistically insignificant and inconsistent findings, even from cohort studies and meta-analyses. The pooled risk estimates are small and insignificant even for the highest noise exposure categories. The role of confounding factors, including air pollution is being investigated.

The link between noise and special groups, such as those annoyed by noise and noise-sensitive individuals, could also be explained by the common factor of underlying ill health; this might account for noise sensitivity that leads to annoyance, and also to cardiovascular diseases. It is therefore prudent to consider the exposure-response relationships as provisional, subject to further studies that can settle the uncertainties, confounding factors, and biases that interfere with the hypothesized relationships on noise, stress, and health.

As a final note, the relevance and applicability of overseas studies on environmental noise and cardiovascular diseases shall be discussed. Physiologically, the response of the human body to external stimuli such as noise is common to all races. However, the magnitude of such response, whether manifested as physiological adaptation or pathological development (leading to diseases), depends on the exposure – the noise level, frequency, duration, and other characteristics of noise, the time of the day (or night), and the recipient himself / herself – the age, the health status, whether the person is noise-sensitive, and other personal factors. Some studies, even done in the same cities, reported different results over time or between different subjects. Thus, one cannot generalize the quantitative exposure-response relationship from overseas studies to the Hong Kong population. Nevertheless, overseas studies are relevant to Hong Kong because a large proportion of our citizens are living in an environment with a moderate to high level of noise, either within our homes or outside. Furthermore, our urban lifestyle, typical of developed cities is associated with a high prevalence of cardiovascular diseases such as hypertension, stroke and ischaemic heart diseases. This literature review is highly relevant to the health of Hong Kong people because many of us are highly exposed to environmental noise, and the 'population attributable to risk' is high, even though the relative risks or odd ratios of these diseases attributable to environmental noise may be low. This observation has a practical public health implication: effective measures to reduce environmental noise will lead to a substantial decline in the risk of cardiovascular diseases.

Chapter Four: Background information of the Hong Kong population according to the survey

To facilitate understanding of response of the Hong Kong to transportation noise in terms of annoyance and sleep disturbance, this chapter outlines the findings of the social survey which are relevant to the issues at hand. Factors which can possibly account for variations in annoyance and sleep disturbance will be highlighted in the discussion below.

4.1 Demographic characteristics of the sample in comparison with Hong Kong population

The purpose of this section is to provide demographic characteristics of the sample and examine its representativeness of the Hong Kong population.

4.1.1 Socio-economic profile of the respondents

The survey reported that 46.8% of the respondents were male, and 53.2% were female.

Table 4.1 shows the age distribution.

Table 4.1: Age proportion (Source: This Study)

Age	n	%
18-24	661	6.6
25-34	1439	14.3
35-44	2222	22.1
45-54	2329	23.1
55-64	1511	15.0
65 or above	1915	19.0
Total	10077	100.0

The proportion of each type of housing is shown in Table 4.2. Each type of housing was built by either the government or private providers detailed below:

- Public rental housing (including rental flats of Housing Authority and Housing Society);
- Housing Authority Tenants Purchase Scheme/ Buy-or-rent Option Scheme blocks;
- Housing Authority Home Ownership Scheme/ Private Sector Participation Scheme/ Middle Income Housing Scheme blocks;
- Housing Society Flat for Sale Scheme blocks;
- Housing Society Sandwich Class Housing Scheme blocks;
- All the above exclude premium-paid flats.

Private housing comprises the following classifications:

- Private residential flats (including Housing Society Urban Improvement Scheme blocks and premium-paid government subsidized flats);

- Other permanent housing (including hotels, hostels, dormitories and other residential flats and staff quarters in non-domestic buildings);
- Temporary housing (including rooftop structures, mobile dwellings, wooden houses and non-domestic purpose areas).

Table 4.2: Distribution of the type of housing (Source: This Study)

Housing Type	n	%
Public rental housing	3603	35.8
Housing Authority Tenants Purchase Scheme/ Buy-or-rent Option Scheme blocks	441	4.4
Housing Authority Home Ownership Scheme/ Private Sector Participation Scheme/ Middle Income Housing Scheme blocks	1152	11.4
Housing Society Flat for Sale Scheme blocks	15	0.1
Housing Society Sandwich Class Housing Scheme blocks	33	0.3
Private residential flats	4665	46.3
Other permanent housing	113	1.1
Temporary housing	55	0.5
Total	10077	100.0

Table 4.3: Highest education level attained of respondents in public/ private housing (Source: This Study)

Education Level Attained	Public		Private		All	
	n	Col %	n	Col %	n	Col %
No schooling, illiterate	259	4.9	97	2.0	356	3.5
Attended some classes, know a few words	221	4.2	105	2.2	326	3.2
Kindergarten	21	0.4	13	0.3	34	0.3
Primary (P.1-P.3)	396	7.6	191	4.0	587	5.8
Primary (P.4-P.6)	1005	19.2	444	9.2	1449	14.4
Lower secondary (F.1-F.3)	1106	21.1	613	12.7	1719	17.1
Upper secondary (F.4-F.5)	1566	29.9	1680	34.8	3246	32.2
Matriculation (F.6-F.7)	199	3.8	290	6.0	489	4.9
Project Yi Jin	8	0.2	5	0.1	13	0.1
Technical/ vocational training (craft course/ apprenticeship)	11	0.2	3	0.1	14	0.1
Technical/ vocational training (certificate courses)	34	0.6	48	1.0	82	0.8
Tertiary education: (Sub-degree courses)	138	2.6	262	5.4	400	4.0
Tertiary education: (Undergraduate courses)	234	4.5	804	16.6	1038	10.3
Tertiary education: (Master’s / doctor’s courses)	46	0.9	278	5.8	324	3.2
Total	5244	100.0	4833	100.0	10077	100.0

Table 4.3 shows the highest education attained for Hong Kong as a whole and for those in public and private housing separately. Generally speaking, respondents living in the private housing attain higher education levels than those in public housing. A notable difference has been found in tertiary education (sub-degree courses, undergraduate courses and master's/ doctor's courses) between public and private housing respondents – more than one-fourth respondents in private housing have attained tertiary education, but very few for those in public housing.

There are also differences in the occupation of those accommodated in private and public housing (Table 4.4). For comparison, the corresponding figures from the 2006 by-census are also given. In the 2006 by-census, about one-third of respondents held professional and/or managerial positions (associate professionals, professionals, managers and administrators), another one-third respondents worked as clerks, service and shop sales workers, skilled agricultural and fishery workers, crafted and related workers; the rest worked as operators and assemblers and other elementary service workers. Reported from this study in 2010, a little less than one-third respondents held professional and/or managerial positions; however, within which, more professionals and managers were reported. Secondly, about 48% respondents (more than that reported in 2006 by-census) worked as clerks, service and shop sales workers, skilled agricultural and fishery workers, crafted and related workers. Lastly, the primary industry of operators, assemblers and elementary services is declining.

There is also a difference between respondents in public/ private housing reflected in the survey of this study. In public housing, most respondents work as service workers and shop sales workers, elementary occupations and clerks. In private housing, most respondents work as managers and administrators, clerks and services workers and shop sales workers.

Table 4.4: Types of occupation of respondents in public/ private housing with reference to Hong Kong 2006 population by-census (Source: This Study)

Occupation	Public		Private		All		2006 by-census	
	n	%	n	%	n	%	n	%
Managers and administrators	181	6.5	629	20.6	810	13.9	361,891	10.8
Professionals	101	3.6	345	11.3	446	7.6	205,435	6.1
Associate professionals	202	7.2	403	13.2	605	10.3	542,309	16.1
Clerks	479	17.1	595	19.5	1074	18.4	567,964	16.9
Service workers and shop sales workers	646	23.1	537	17.6	1183	20.2	550,855	16.4
Skilled agricultural and fishery workers*	1	0	3	0.1	4	0.1	9,639	0.3
Craft and related workers	351	12.6	179	5.9	530	9.1	286,007	8.5
Plant and machine operators and assemblers	241	8.6	132	4.3	373	6.4	208,409	6.2
Elementary occupations	594	21.2	227	7.4	821	14.0	633,227	18.8
Total	2796	100.0	3050	100.0	5846	100.0	3,365,736	100.0

* "Skilled agricultural and fishery workers" in the 2006 population by-census is defined as "skilled agricultural and fishery workers" AND "occupations not classifiable".

The differences in education attainment and occupation of those living in public and private housing are also reflected in the average household monthly income (Table 4.5). Generally speaking, respondents living in the private housing have higher monthly household income than those in public housing.

Analysis of the data shows that the 25^{th}, 50^{th} and 75^{th} percentiles of the monthly household income for public housing are $8000, $12500 and $20000 respectively, and the corresponding figures for private housing are $10000, $20000 and $30000 respectively.

Comparing between the survey results in this study and the 2006 population by-census, the study results seemed to have the same household income levels in the 50^{th} and 75^{th} percentiles with the 2006 by-census; however, the 25^{th} percentile has been decreased in the present day from $6000 (2006 by-census) to $5000 (this study).

Table 4.5: Average monthly household income of respondents in public/ private housing with reference to Hong Kong 2006 population by-census (Source: This Study & C&SD 2006 population by-census)

Average monthly household income	Public		Private		All		2006 population by-census	
	n	%	n	%	n	%	n	%
$70,000 or above	22	0.4	306	6.3	328	3.3	183,750	8.3
$60,000 – $69,999	30	0.6	152	3.1	182	1.8		
$50,000 – $59,999	66	1.3	288	6.0	354	3.5	194,723	8.7
$40,000 – $49,999	190	3.6	449	9.3	639	6.3		
$30,000 – $39,999	442	8.4	**650**	**13.4**	**1092**	**10.8**	**221,101**	**9.9**
$25,000 – $29,999	426	8.1	419	8.7	845	8.4	162,783	7.3
$20,000 – $24,999	**609**	**11.6**	**547**	**11.3**	1156	11.5	225,292	10.1
$15,000 – $19,999	781	14.9	511	10.6	**1292**	**12.8**	**279,217**	**12.5**
$12,500 – $14,999	**446**	**8.5**	254	5.3	700	6.9	339,469	15.2
$10,000 – $12,499	512	9.8	**320**	**6.6**	832	8.3		
$9,000 – $9,999	195	3.7	105	2.2	300	3.0	147,081	6.6
$8,000 – $8,999	**218**	**4.2**	130	2.7	348	3.5		
$7,000 – $7,999	186	3.5	96	2.0	282	2.8	**146,010**	**6.6**
$6,000 – $6,999	204	3.9	109	2.3	313	3.1		
$5,000 – $5,999	200	3.8	100	2.1	**300**	**3.0**	121,605	5.5
$4,000 – $4,999	183	3.5	92	1.9	275	2.7		
$3,000 - $3,999	217	4.1	94	1.9	311	3.1	118,779	5.3
$2,000 – $2,999	201	3.8	81	1.7	282	2.8		
$1,000 - $1,999	45	0.9	42	0.9	87	0.9	86,736	3.9
$1 - $999	1	0	7	0.1	8	0.1		
No income	70	1.3	81	1.7	151	1.5		
Total	5244	100.0	4833	100.0	10077	100.0	2,226, 546	100.0

4.1.2 Shift workers

Whether or not the respondent is a shift worker may be a determining factor of annoyance reaction to transportation noise. The work and sleep pattern may also affect whether or not one can sleep well. Table 4.6 shows the employment status of the sample according to the survey. It can be seen that 58% respondents are employed, full-time or part-time. Others are not employed, including students, housewives and retired persons. Of those who are employed, less than 10% have taken up the overnight shift work. Of those who have to work night shifts, only about one-fourth has to take the night shift almost every night.

While the percentage of those who take the shift work is small, it is however large enough to analyze the differences on the response between shift workers and non-shift workers.

Table 4.6: Employment status (Source: This Study)

<table>
<tr><th>Employment Status</th><th>n</th><th>%</th><th></th><th>n</th><th>%</th><th></th><th>n</th><th>%</th></tr>
<tr><td rowspan="5">Employed</td><td rowspan="5">5846</td><td rowspan="5">58.0</td><td>Non-overnight Shift Work</td><td>5321</td><td>91.0
(Employed total percent with total N = 5846)
52.8
(Overall percent with total N = 10077)</td><td colspan="3"></td></tr>
<tr><td rowspan="3">Overnight Shift Work</td><td rowspan="3">525</td><td rowspan="3">9.0
(Employed total percent with total N = 5846)
5.2
(Overall percent with total N = 10077)</td><td>Frequently Work overnight shift</td><td>136</td><td>25.9
(Overnight shiftwork total percent with total N = 525)
1.3
(Overall percent with total N = 10077)</td></tr>
<tr><td>Alternatively Work day & night shift</td><td>389</td><td>74.1
(Overnight shiftwork total percent with total N = 525)
3.9
(Overall percent with total N = 10077)</td></tr>
<tr><td>Total</td><td>525</td><td>100.0</td></tr>
<tr><td>Total</td><td>5846</td><td>100.0</td><td colspan="3"></td></tr>
<tr><td>Not Employed</td><td>4231</td><td>42.0</td><td colspan="6" rowspan="2"></td></tr>
<tr><td>Total</td><td>10077</td><td>100.0</td></tr>
</table>

4.2 Characteristics of living environment

Information on this section was obtained from the early parts of the questionnaire when respondents were unaware of the purpose of the survey and before any question about noise was mentioned. They were also given the opportunity to respond spontaneously without any mention of noise.

Recognizing that whether one is satisfied with the neighborhood environment is a potential determinant of annoyance reaction, the respondents were first asked to rate their degree of satisfaction with the neighborhood environment. The results in Table 4.7 shows that about two-thirds respondents are satisfied living in the estate/ street block and only very few are dissatisfied.

Table 4.7: Distribution of the level of satisfaction with the estate/ street block as a place to live (Source: This Study)

Level of satisfaction with the estate/ street block	n	%
Highly dissatisfied	65	0.6
Dissatisfied	622	6.2
Neither satisfied or dissatisfied	2542	25.2
Satisfied	6486	64.4
Highly satisfied	362	3.6
Total	10077	100.0

4.2.1 Dwelling unit conditions

4.2.1.1 Distribution of public/ private housing

As aforementioned, public housing accounts for 52% of the cases whereas the rest 48% are private.

4.2.1.2 Length of residence

The results show that nearly 80% respondents reported to have lived at a particular location for less than 20 years (Figure 4.1). It is observed that people have resided in public housing for a longer period than in private housing. This is attributed to the low residential mobility of public housing residents because in the government built and subsidized housing, relocation is normally not allowed without compelling reasons. In contrast, people in private housing are free to move particularly if their income changes.

The length of residence at an address is a potential factor affecting annoyance because it is believed by some that people may adapt to noise, and the longer one lives at a place, the more tolerant to noise that person is. This notion will be tested in the binary logistic regression described in Section 6.6.

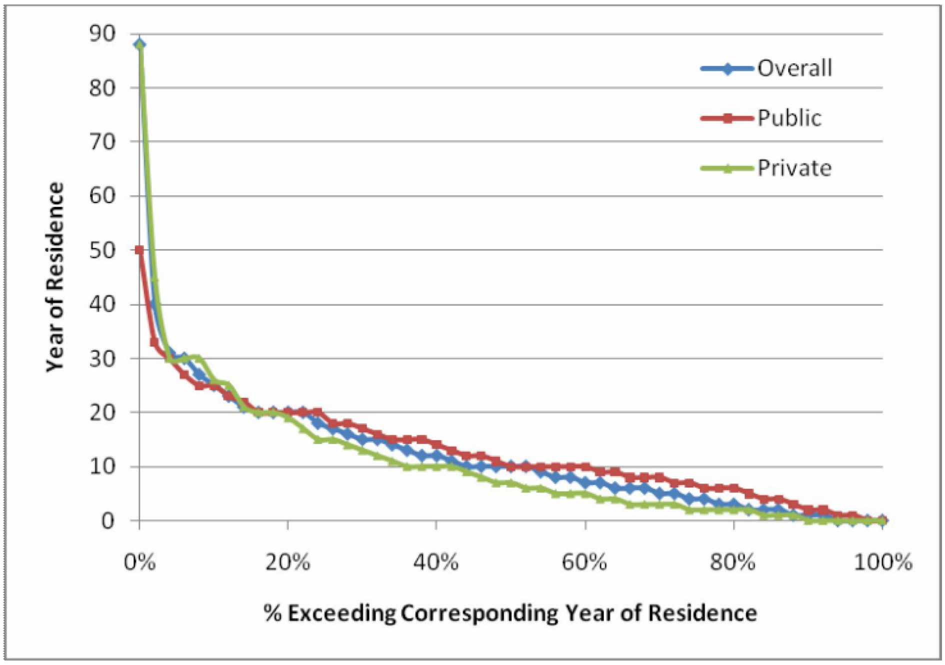

Figure 4.1: Cumulative frequency curves of duration of present residence (year) of respondent in public/ private housing (n=10077 with 5244 public and 4833 private) (Source: This Study)

4.2.1.3 Number of rooms in the dwelling

Information on the number of rooms in their dwellings was collected. For the purpose of reporting, the total number of rooms is defined as the sum of living and dining rooms, bed and maid rooms, study and store rooms. A studio type living quarters is considered as a single room in this section and in Section 4.2.1.4.

The number of rooms in a dwelling is a measure of socio-economic status as well as a surrogate of internal noise generated from within the dwelling. The latter is important because it can mask any noise coming from outside.

Table 4.8 shows the proportion of the total number of rooms of dwellings in public/ private housing. It can be observed that public housing, as expected, has fewer rooms than private housing.

Table 4.8: Distribution of the total number of rooms of dwellings in public/ private housing (Source: This Study)

	Public		Private		All	
Total number of rooms in a living quarters	n	%	n	%	n	%
1-3	2914	55.6	2465	51.0	5379	53.4
4-6	1158	22.1	2012	41.6	3170	31.5
7 or above	1	0	65	1.3	66	0.7
Studio type living quarters	1171	22.3	291	6.0	1462	14.5
Total	5244	100.0	4833	100.0	10077	100.0

Also, studio type living quarters account for almost one-fourth of public housing, but only a small percentage in the private housing. This is particular common among older public housing estates which were built at a time when the priority was to provide accommodation rather than privacy.

4.2.1.4 Crowdedness

As indicated earlier, crowdedness is a potential factor affecting human response to transportation noise. It is measured in two ways in this study. Firstly, it is derived from dividing the total number of bedrooms (including those of domestic helpers) by the number of household members. Secondly, it can also be determined by dividing total number of rooms, of all types and uses, in the household by the number of household members. The household members are defined as persons who usually stay in this household and have lived in Hong Kong for at least one month in the past 6 months or will live in Hong Kong for at least one month in the coming 6 months, including the live-in foreign domestic helpers.

Figure 4.2 and Table 4.9 show the first measure of crowdedness taking into account only the bed room and the room for domestic helper. Genereally speaking, private housing respondents have more number of rooms per person than that in the public housing.

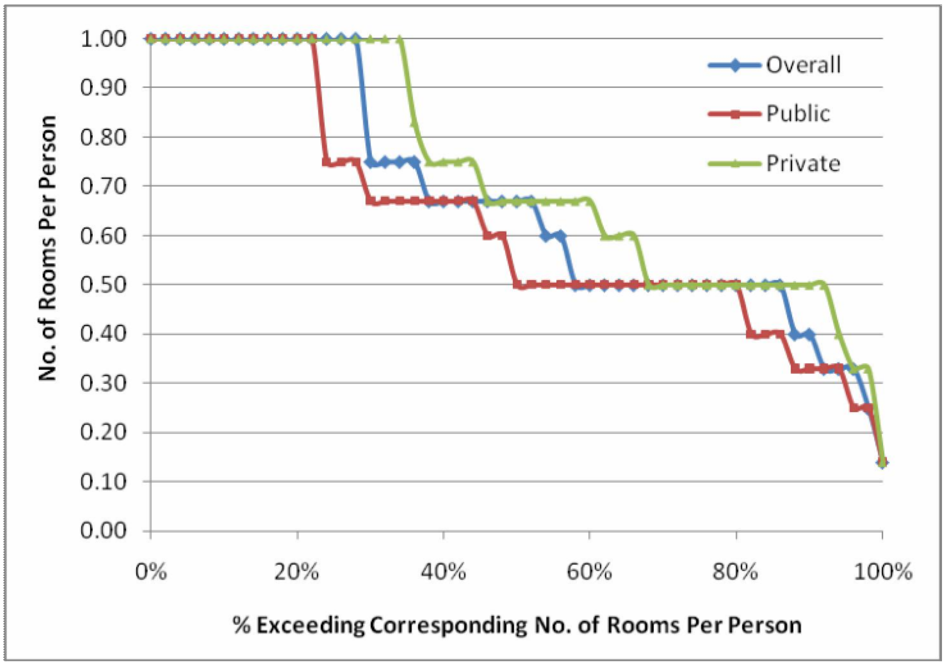

Figure 4.2: Cumulative frequency curves of crowdedness* in public/ private housing (*number of bedrooms/ maidrooms divided by the number of household members in the household) (n=10077 with 5244 public and 4833 private) (Source: This Study)

Table 4.9: Number of rooms (bedrooms/ maidrooms) per person in public/ private housing (Source: This Study)

Number of rooms (Bedrooms/ maidrooms) per person	Public		Private		All	
	n	%	n	%	n	%
0.00-0.09	0	0.0	0	0.0	0	0.0
0.10-0.19	5	0.1	3	0.1	8	0.1
0.20-0.29	284	5.4	57	1.2	341	3.4
0.30-0.39	443	8.4	157	3.2	600	6.0
0.40-0.49	258	4.9	157	3.2	415	4.1
0.50-0.59	1664	31.7	1250	25.9	2914	28.9
0.60-0.69	1032	19.7	1022	21.1	2054	20.4
0.70-0.79	342	6.5	408	8.4	750	7.4
0.80-0.89	1	0.0	46	1.0	47	0.5
0.90-0.99	0	0.0	0	0.0	0	0.0
1.00-1.09	1215	23.2	1733	35.9	2948	29.3
Total	5244	100.0	4833	100.0	10077	100.0

If all kinds of rooms are taken into consideration (Figure 4.3 and Table 4.10), the relative degree of crowdedness is the same.

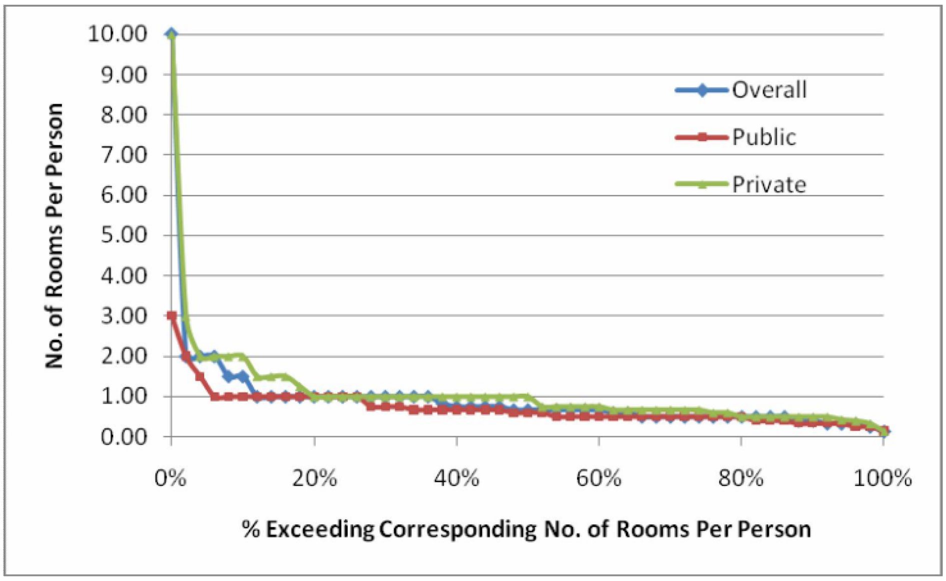

Figure 4.3: Cumulative frequency curves of crowdedness* in public/ private housing (*number of bedrooms/ maidrooms plus study rooms/ storerooms divided by the number of household members in the household) (n=10077 with 5244 public and 4833 private) (Source: This Study)

Table 4.10: Number of rooms (bedrooms/ maidrooms and study rooms/ store rooms) per person in public/ private housing (Source: This Study)

Number of rooms (Bedrooms/ maidrooms and study rooms/ store rooms) per person	Public		Private		All	
	n	%	n	%	n	%
0.00-0.09	0	0.0	0	0.0	0	0.0
0.10-0.19	5	0.1	2	0.0	7	0.1
0.20-0.29	281	5.4	52	1.1	333	3.3
0.30-0.39	429	8.2	113	2.3	542	5.4
0.40-0.49	251	4.8	128	2.6	379	3.8
0.50-0.59	1543	29.4	717	14.8	2260	22.4
0.60-0.69	970	18.5	891	18.4	1861	18.5
0.70-0.79	359	6.8	438	9.1	797	7.9
0.80-0.89	4	0.1	70	1.4	74	0.7
0.90-0.99	0	0.0	0	0.0	0	0.0
1.00-1.09	1185	22.6	1547	32.0	2732	27.1
1.10-1.99	83	1.6	371	7.7	454	4.5
2.00-2.99	117	2.2	394	8.2	511	5.1
3.00-3.99	17	0.3	94	1.9	111	1.1
4.00-4.99	0	0.0	9	0.2	9	0.1
5.00-5.99	0	0.0	5	0.1	5	0.0
6.00-6.99	0	0.0	1	0.0	1	0.0
7.00-7.99	0	0.0	0	0.0	0	0.0
8.00-8.99	0	0.0	0	0.0	0	0.0
9.00-9.99	0	0.0	0	0.0	0	0.0
10.00-10.99	0	0.0	1	0.0	1	0.0
Total	5244	100.0	4833	100.0	10077	100.0

A number of observations can be drawn from the above tables and diagrams. Private housing residents have more number of rooms per person than that in the public housing. The maximum number of rooms per person for public hosuing can be as many as three, and ten for private housing. In public housing estates, the number of rooms is restricted by the planning criteria set by the government and is much smaller.

4.2.1.5 Dwellings with bedrooms not directly facing a road/ rail (access to quiet room)

The access to a "quiet side" in a dwelling is known to be a significant factor shaping human annoyance response to transportation noise in several previous studies (Persson Waye et al., 2003; Bluhm et al., 2004; Babisch et al., 2005; Gidlof-Gunnarsson et al., 2007; Botteldooren et al., 2011). In previous studies, particularly those in Europe, the "quiet side" refers to the side of a house which is protected from the exposure to road or railway noises (e.g. courtyard, quiet back streets, cules-de-sac). In Hong Kong such urban settings are rare. What we did in this study was to ascertain whether the residents in a particular dwelling have access to any bedroom which is not directly exposed to road/ rail noise sources. With such a definition, if the occupant of a studio type living quarters in public housing has partitioned the dwelling into small cubicles, and if one of them is used as a bedroom, it will not have a window (hence not facing the road/ rail). In such cases it is deemed to be having access to a quiet room.

Table 4.11 shows the proportion of dwellings with or without a quiet room in public/ private housing. It can be seen that more than 40% respondents in Hong Kong have a quiet room living in their dwellings. This apparently high percentage can be attributed to a number of reasons, including the creation of small window-less small crucibles in a dwelling and also the use of temporary partitioning to create bed space for sleeping at night. It would be interesting in this study to examine if access to quiet room determines annoyance reactions in Hong Kong.

Table 4.11: Distribution of dwellings with or without a quiet room in public/ private housing (Source: This Study)

Quiet room	Public		Private		All	
	n	%	n	%	n	%
Without	2682	51.1	2676	55.4	5358	53.2
With	2562	48.9	2157	44.6	4719	46.8
Total	5244	100.0	4833	100.0	10077	100.0

4.2.1.6 Air-conditioning in living room and bedroom

Located in the sub-tropics, most of the dwellings in Hong Kong are fitted with air conditioners (Table 4.12). The figures show that more than 83% dwellings in public housing have air-conditioning in living/ dining and bed rooms, and the corresponding figure for private housing is more than 95%.

Table 4.12: Distribution of dwellings with air-conditioning in the living room/ dining room and bedroom in public/ private housing (Source: This Study)

	Public	Private	All
Have air-conditioning in living room/ dining room	89.7%	95.8%	92.6%
Have air-conditioning in bedroom	83.5%	97.5%	90.2%
n	5244	4833	10077

4.2.1.7 Closing windows

This sub-section reports on the usual habits of respondents closing windows during sleep and during the day (Tables 4.13 and 4.14). The figures show that about one-fourth dwellings close windows a lot or nearly all the time during their sleeps and during the day. The proportion is slightly higher for private housing than public.

Table 4.13: Distribution of respondents who slept with windows closed in public/ private housing (Source: This Study)

	Public		Private		All	
Sleep with windows closed	n	%	n	%	n	%
Never	1316	25.1	883	18.3	2199	21.8
Sometimes	2827	53.9	2427	50.2	5254	52.1
A lot	641	12.2	839	17.4	1480	14.7
Nearly all the time	372	7.1	676	14.0	1048	10.4
Not applicable (no windows)	88	1.7	8	0.2	96	1.0
Total	5244	100.0	4833	100.0	10077	100.0

Table 4.14: Distribution of respondents who kept the windows closed during the day time when there are people at home in public/ private housing (Source: This Study)

	Public		Private		All Respondents	
Keep windows closed during day time where there are people at home	n	%	n	%	n	%
Never	1719	32.8	1276	26.4	2995	29.7
Sometimes	2620	50.0	2306	47.7	4926	48.9
A lot	633	12.1	850	17.6	1483	14.7
Nearly all the time	266	5.1	394	8.2	660	6.5
Not applicable (no windows)	6	0.1	7	.1	13	0.1
Total	5244	100.0	4833	100.0	10077	100.0

4.2.1.8 Coping behaviors

a) Turning on air-conditioner

Table 4.15 shows the proportion of respondents who switched on the air-conditioning while bothered by outside noise at home in the past twelve months, for public and private housing respectively.

The data show that only a relatively small proportion of respondents (2.5%) turn on air-conditioners for most or all of the time to counteract the noise from outside. Also, the percentage of doing so for most or all of the time is slightly higher in private housing than in public. In other words, most people turn on air-conditioner for non-acoustic, climatic reasons.

Table 4.15: Distribution of respondents who switched on the air-conditioner while bothered by outside noise at home in the past twelve months in public/ private housing (Source: This Study)

	Public		Private		All	
Switched on the air-conditioner while bothered by outside noise at home in the past twelve months	n	%	n	%	n	%
Never	4525	86.3	4099	84.8	8624	85.6
Sometimes	612	11.7	591	12.2	1203	11.9
A lot	102	1.9	122	2.5	224	2.2
Nearly all the time	5	0.1	21	0.4	26	0.3
Total	5244	100.0	4833	100.0	10077	100.0

b) Closing windows

In contrast to air-conditioning, 19.5% more people relied on closing windows (i.e. sometimes, a lot, nearly all the time) to counteract the external noise at home in the past twelve months. The data show that almost 10% respondents closed the windows for most or all of the time to counteract the noise from outside (Table 4.16). Also, the percentage of doing so for most or all of the time is higher in private housing than in public.

Table 4.16: Distribution of respondents who closed the windows while bothered by outside noise at home in the past twelve months in public/ private housing (Source: This Study)

	Public		Private		All	
Closed the windows while bothered by outside noise at home in the past twelve months	n	%	n	%	n	%
Never	3605	68.7	3054	63.2	6659	66.1
Sometimes	1257	24.0	1217	25.2	2474	24.6
A lot	307	5.9	402	8.3	709	7.0
Nearly all the time	75	1.4	160	3.3	235	2.3
Total	5244	100.0	4833	100.0	10077	100.0

4.2.2 Noise sensitivity

Noise sensitivity is measured by a total of 7 questions based on which a composite score is built and the results for Hong Kong are shown in Figure 4.4 and Table 4.17.

Some differences can be found in the noise sensitivity of respondents in public/ private housing. Generally speaking, residents of the private housing estates are less noise sensitive. The difference is particularly noticeable toward the upper end where 6.3% respondents in public housing reported noise sensitivity scores above 27, as compared to 5.8% in private housing.

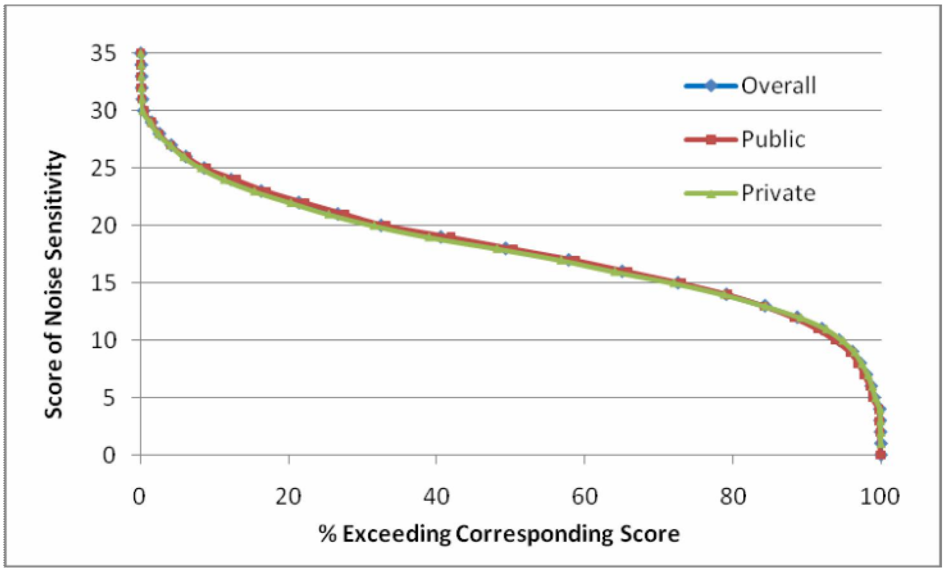

Figure 4.4: Cumulative frequency curves of noise sensitivity scores (higher scores represent more noise sensitive) in public and private housing (n=10037 with 5222 public and 4815 private) (Source: This Study)

Table 4.17: Distribution of noise sensitivity scores of respondents in public/ private housing (higher scores represent more noise sensitive) (Source: This Study)

	Public		Private		All Respondents	
Noise Sensitivity Score	n	%	n	%	n	%
0-5	61	1.2	36	0.7	97	1.0
6-10	261	5.0	213	4.4	474	4.7
11-15	1086	20.8	1098	22.8	2184	21.8
16-20	2077	39.8	1950	40.5	4027	40.1
21-25	1271	24.3	1125	23.4	2396	23.9
26-30	441	8.4	380	7.9	821	8.2
31-35	25	0.5	13	0.3	38	0.4
Total	5222	100.0	4815	100.0	10037	100.0

Chapter Five: Noise sources, noise annoyance, sleep disturbance and other effects in Hong Kong

Based on the results of the social survey, this chapter reports on the noise sources in Hong Kong and the extent to which the Hong Kong population is annoyed by different sources of noise. The survey also provided information on how people coped with the noise and how they perceived the impact of noise on their quality of their sleep. Some initial findings on the self-reported health status of the Hong Kong population are also given, but they should be interpreted with caution because establishing the casual link with noise requires a lot more information that is above and beyond the limit of the current study.

5.1 Noise sources and extent of annoyance in Hong Kong

To obtain information on the sounds that people hear from sources outside the dwelling, the respondents were probed in the following three ways.

- The respondents were asked to name three negative and three positive aspects of living in the estate/ street block. The interviewers were asked to note if noise or the acoustic environment was named. Because the respondent is not prompted, any mention of the acoustic environment, in a negative or positive manner, is a useful indicator of the importance of noise/ sound in urban living.
- The respondents were asked to rate their level of annoyance with respect to a specific list of noise sources. This is reported as the percentage of respondents reporting a high level of annoyance, as defined in Section 2.2.2, with respect to that noise source. This is a reliable measure of the annoyance which can be used to compare the annoyance caused by different noise sources and for comparison with findings in other countries/ surveys.
- Toward the end of the interview, the respondents were asked a supplementary question prompting them to mention up to three sources of noise that bothered, disturbed or annoyed them. The information so obtained was used to checked consistency and validity of earlier responses/ answers.

5.1.1 Importance of noise/ sound in urban living

Table 5.1 shows the proportion of respondents naming noise as one of the three negative aspects of living in the respondent’s estate/ street block. It is notable that noise is the most commonly mentioned negative aspect, accounting for almost one-third of the responses. The second and third most common negative aspects are convenience of transport and hygiene respectively. Such finding highlights the significance of noise to people in Hong Kong. It is worthy to note that noise is considered more important than air quality as a local environmental issue.

Table 5.1: Distribution of three negative aspects of living in the estate/ street block (Source: This Study)

Negative aspect living in the estate/ street block	First mention		Second mention		Third mention		Total	
	n	%	n	%	n	%	n	%
Sound/ noise	1655	**32.7**	529	**23.2**	161	**19.4**	2345	**28.7**
Air quality	375	7.4	271	**11.9**	87	**10.5**	733	9.0
Hygiene	449	**8.9**	252	**11.1**	95	**11.4**	796	**9.7**
Environment	298	5.9	125	5.5	50	6.0	473	5.8
Estate facilities	333	6.6	182	8.0	82	9.9	597	7.3
Community support facilities	102	2.0	97	4.3	56	6.7	255	3.1
Convenience of shopping/ dining/ entertainment	347	6.9	235	10.3	78	9.4	660	8.1
Convenience of transport	728	**14.4**	226	9.9	84	10.1	1038	**12.7**
Relatives/ friends/ neighbors' relationship	57	1.1	22	1.0	7	0.8	86	1.1
Public order/ estate management	400	7.9	205	9.0	79	9.5	684	8.4
Outlook/ structural safety of building	262	5.2	106	4.7	36	4.3	404	4.9
Property price/ rent/ management fee	47	0.9	17	0.7	11	1.3	75	0.9
Coverage of telecom/broadband/TV network	4	0.1	11	0.5	5	0.6	20	0.2
Total	5057	100.0	2278	100.0	831	100.0	8166	100.0

Table 5.2: Distribution of three positive aspects of living in the estate/ street block (Source: This Study)

Positive aspect living in the estate/ street block	First mention		Second mention		Third mention		Total	
	n	%	n	%	n	%	n	%
Sound/ noise	1140	**13.6**	414	9.9	122	8.2	1676	**11.9**
Air quality	1851	**22.0**	498	**11.9**	116	7.8	2465	**17.5**
Hygiene	168	2.0	160	3.8	86	5.8	414	2.9
Environment	465	5.5	390	9.3	161	10.8	1016	7.2
Estate facilities	122	1.5	122	2.9	46	3.1	290	2.1
Community support facilities	103	1.2	114	2.7	84	5.6	301	2.1
Convenience of shopping/ dining/ entertainment	538	6.4	1042	**24.9**	287	**19.2**	1867	**13.3**
Convenience of transport	3061	**36.4**	775	**18.5**	216	**14.4**	4052	**28.8**
Relatives/ friends/ neighbors' relationship	166	2.0	121	2.9	95	6.4	382	2.7
Public order/ estate management	626	7.5	470	11.2	233	**15.6**	1329	9.4
Outlook/ structural safety of building	16	0.2	19	0.5	14	0.9	49	0.3
Property price/ rent/ management fee	143	1.7	61	1.5	33	2.2	237	1.7
Coverage of telecom/broadband/TV network	1	0.0	1	0.0	2	0.1	4	0.0
Total	8400	100.0	4187	100.0	1495	100.0	14082	100.0

Conversely, when the respondents were asked to mentioned those positive aspects which appeal to them, convenience of transport is the most common positive aspect mentioned, accounting for almost one-third (Table 5.2). The second and third most common positive aspects are air quality and convenience of shopping/ dining/ entertainment respectively. The acoustic environment (sound/ noise) ranks the fourth most commonly mentioned positive aspect, indicating that few people rate the acoustic environment favorably. It suggests there is room for improving the acoustic environment in Hong Kong.

5.2 Annoyance responses to a specific list of noise sources

5.2.1 Annoyance reaction

Following the ISO protocol, the respondents were asked to rate their level of annoyance on a 0 to 10 scale. The respondents were separately asked to rate the annoyance during the whole day, at night and the level of sleep disturbance. As elaborated before, respondents giving a rating of 8, 9 or 10 on the 0 to 10 numeric scale are classified as “highly annoyed”. Similarly, those reporting sleep disturbance of 8, 9, and 10 on the 0 to 10 numeric scale are considered as “highly sleep disturbed”. These were added up to give the percentage of people “highly annoyed”, “highly annoyed at night” and “highly sleep disturbed” with respect to difference noise sources (Figure 5.1).

As regards annoyance throughout the day, the data in Figure 5.1 and Table 5.3 suggest that the top six noise sources annoying people are, in order of severity, renovation, road traffic, neighborhood, construction/ demolition, animals outside and playgrounds/ sportsgrounds. It should be noted that whilst road traffic is the most prevalent noise source in Hong Kong, it ranks only second to renovation as the noise that annoys people.

Other noise sources considered annoying come from neighbors, construction/ demolition, outside animals and playgrounds. They reflect Hong Kong’s dense population and cramped living environment.

Concerning annoyance at night, the results show that road traffic noise ranks the top highly annoyed noise source at night. Conversely, noise from aircraft, industries/ factories/ machineries and construction/demolition are those mentioned less frequently as the source causing night time annoyance reflecting that they are less prevalent at night.

Comparing of the figures for day time and night time annoyance (Figure 5.1 and Table 5.3); it is observed that the renovation and construction/demolition yield the greatest day-night differences. For example, renovation accounts for 10.8% of highly annoyance response for the whole day while at night, the corresponding figure is only 0.5%. Similar pattern can be observed for construction/ demolition (3.4% for whole day vs. 0.2% for night time). This is in stark contrast to road traffic noise which shows fewer variations over time. The contrast can be ascribed to diurnal pattern that the activities of renovation and construction/demolition are active during the day and are forbidden at night by law.
The data on sleep disturbance will be discussed in Section 5.5.

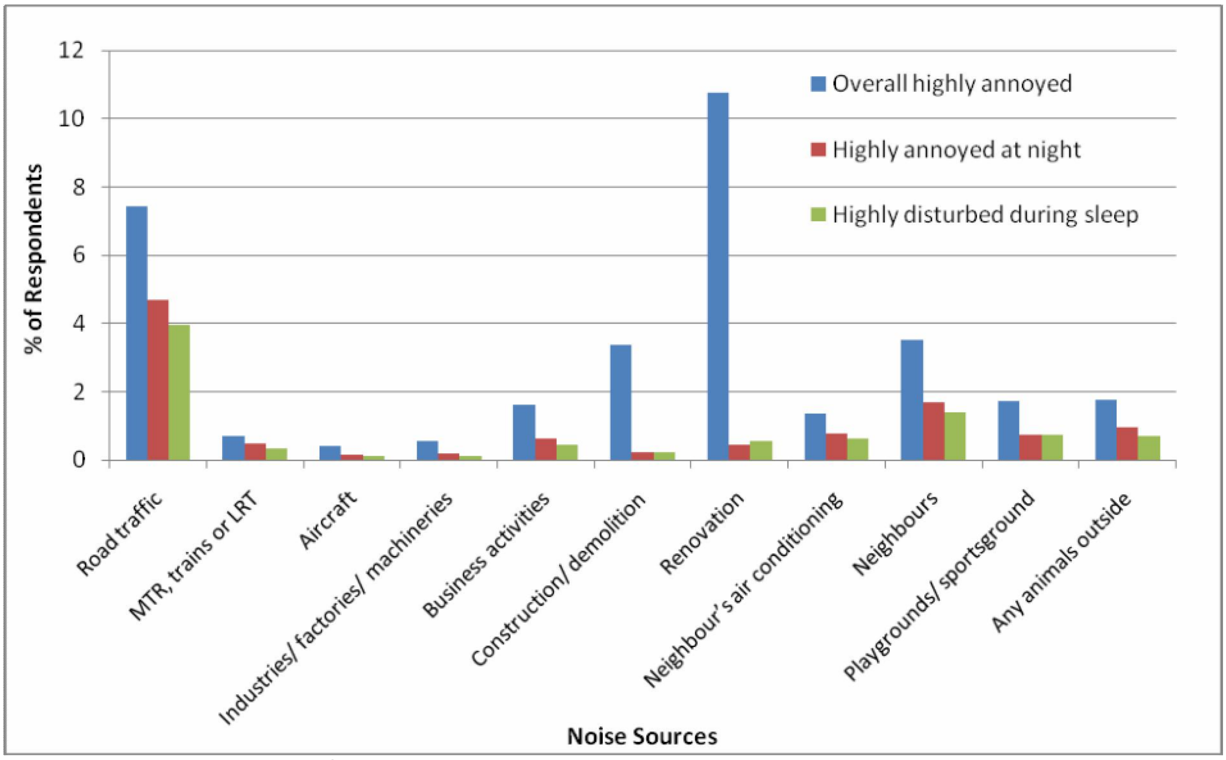

Figure 5.1: Percentages of respondents highly annoyed, highly annoyed at night and sleep highly disturbed by different noise sources (n=10077) (Source: This Study)

Table 5.3: Percentages of respondents highly annoyed, highly annoyed at night and sleep highly disturbed by different noise sources (n=10077) (Source: This Study)

Noise Source	% Highly Annoyed (HA)	% Highly Annoyed at Night (HAN)	% Sleep Highly Disturbed (HSD)
Road traffic	7.9	**4.95**	**4.15**
MTR, trains or LRT	0.7	0.5	0.3
Aircraft	0.4	0.2	0.1
Industries/ factories/ machineries	0.5	0.2	0.1
Commercial activities	1.6	0.6	0.4
Construction/ demolition	3.4	0.2	0.2
Renovation	**10.8**	0.5	0.6
Neighbor's air conditioning	1.4	0.8	0.6
Neighbors	3.5	1.7	1.4
Playgrounds/sports ground	1.7	0.7	0.7
Outside animals	1.8	1.0	0.7

Note: %HA, %HAN, %HSD for the road traffic noise are obtained from the responses of partial 7, 8, 9, and 10 on a 0-10 scale. %HA, %HAN, %HSD for other noise sources are obtained from the responses of 8, 9 and 10 only on a 0-10 scale.

5.2.2 Annoyance response on 5-point scale

The above data are based on the 0-10 annoyance scale, from which the %HA is derived. This study has also solicited the annoyance reaction of inhabitants on the 5-piont verbal scale. The results, given in Appendix 5, suggest that "highly annoyed" correspond fairly well with the two verbal scales on 1 to 5, namely "extremely annoyed" and "very annoyed", or in Cantonese (好嘈) and (極之嘈) respectively.

5.2.3 Supplementary questions as to which noise sources that bother

Table 5.4 shows the proportion of noise sources from outside home named by respondents that bother, disturb or annoy them. It is evident from the results that more than one-third reported road traffic noise as the one that bothers, disturbs or annoys them, followed by renovation and neighbors' noise.

Table 5.4: Distribution of noise sources from outside home that bother, disturb or annoy the respondent (Source: This Study)

Noise sources from outside home bother, disturb or annoy you	First mention		Second mention		Third mention		Fourth mention		Total	
	n	%	n	%	n	%	n	%	n	%
Road traffic	2723	47.4	518	23.1	95	16.8	3	50.0	3339	**39.0**
Renovation	767	13.4	440	19.6	108	19.1	0	0	1315	**15.4**
Neighbors	578	10.1	287	12.8	72	12.8	1	16.7	938	**11.0**
Construction/ demolition	255	4.4	178	7.9	58	10.3	0	0	491	5.7
Animals outside	280	4.9	158	7.1	48	8.5	0	0	486	5.7
Playground/ sportsground	251	4.4	116	5.2	38	6.7	0	0	405	4.7
Noise in public areas	176	3.1	147	6.6	48	8.5	0	0	371	4.3
Business activities	186	3.2	117	5.2	33	5.9	2	33.3	338	4.0
MTR, trains or LRT	102	1.8	78	3.5	7	1.2	0	0	187	2.2
Neighbor's air conditioning	68	1.2	49	2.2	16	2.8	0	0	133	1.6
Residential building services	78	1.4	29	1.3	11	2.0	0	0	118	1.4
Aircraft	70	1.2	24	1.1	5	0.9	0	0	99	1.2
Industries/ factories/ machineries	65	1.1	32	1.4	2	0.4	0	0	99	1.2
Marine	63	1.1	24	1.1	7	1.2	0	0	94	1.1
Alarm	44	0.8	25	1.1	7	1.2	0	0	76	0.9
School	36	0.6	18	0.8	9	1.6	0	0	63	0.7
Sound of wind	2	0	0	0	0	0	0	0	2	0.0
Total	5744	100.0	2240	100.0	564	100.0	6	100.0	8554	100.0

5.3 Sleep patterns, sleep quality, sleep disturbance and night time annoyance

5.3.1 Sleep pattern

Recognizing that one of the effects of transportation noise is “sleep disturbance”, the study collected information on the sleep pattern and sleep quality of the Hong Kong population. Such information will assist understanding of sleep disturbance reported by the respondents. The sleep data will also provide the basic information needed if Hong Kong develops day-evening-night noise standards.

The survey found that most of the respondents (97.9%) sleep once a day (hereafter “primary sleep”), while a small minority sleep more than once a day. For those who do, their sleep periods are referred to as “primary” and “secondary” sleep. A few of them may have different sleeping patterns on different days.

To assess whether Hong Kong people have sufficient sleep, it has been found that over 40% of the respondent in fact sleep more than what they think is needed (Figures 5.2 and 5.3). Sleeping for about eight hours is the point of intersection of the actual and ideal duration of sleep.

The results also show that very few (9.5%) slept for 6 hours or less.

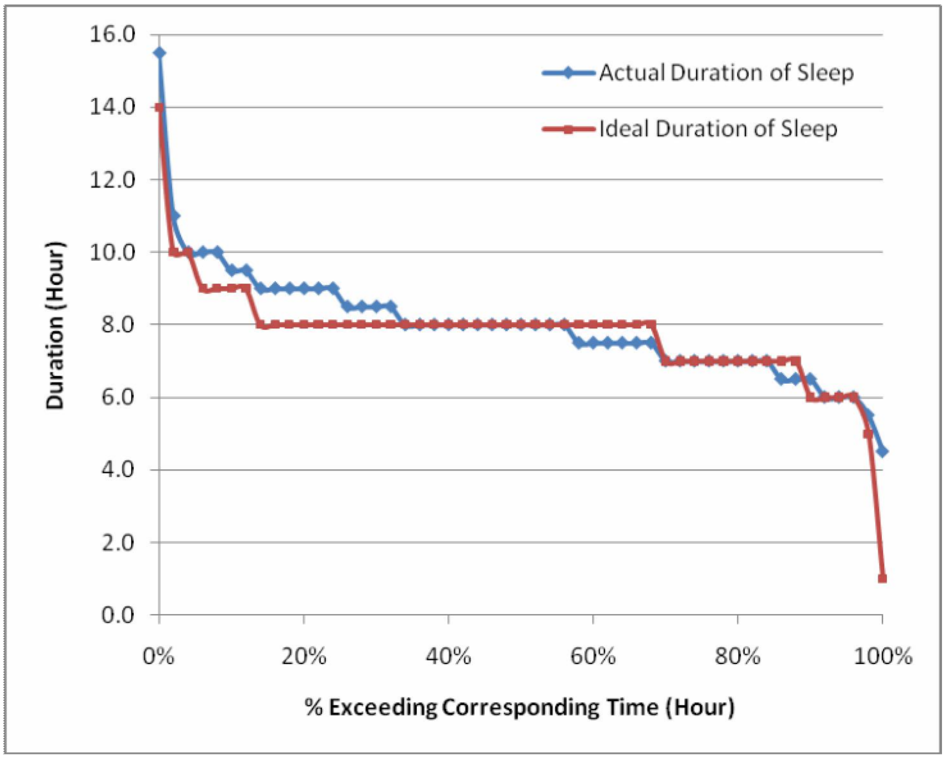

Figure 5.2: Cumulative frequency curves of actual and desirable sleeping durations (n=9866)
(Source: This Study)

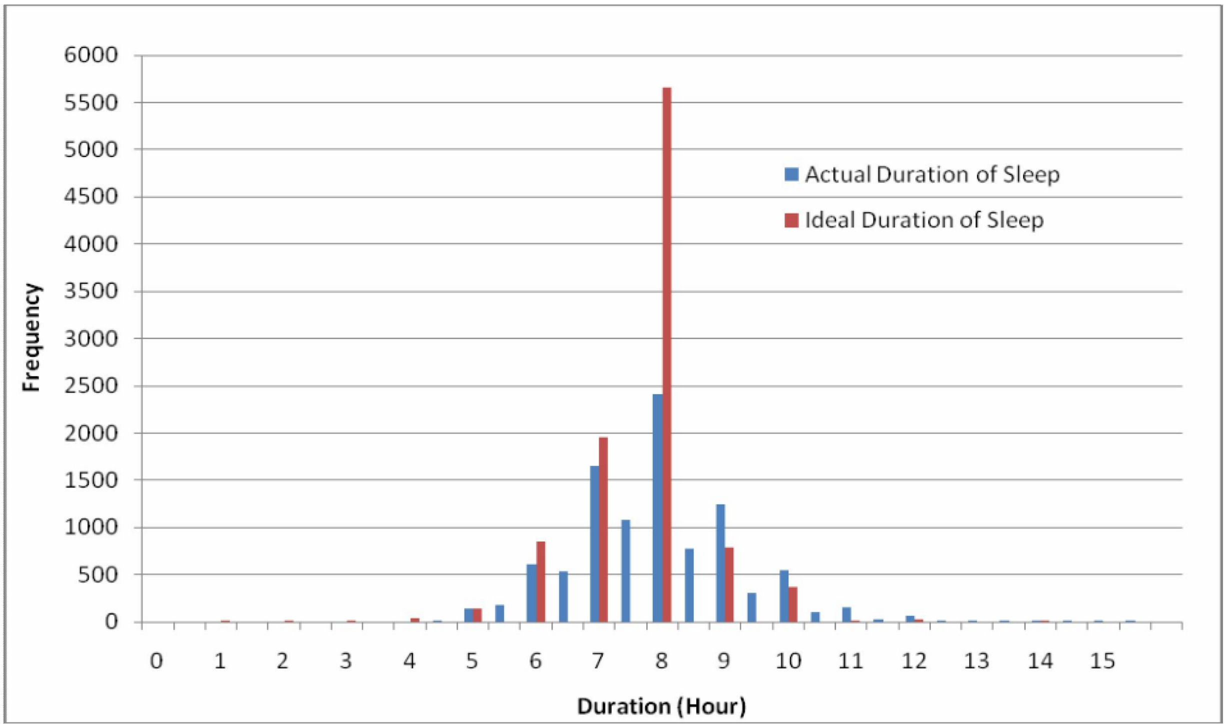

Figure 5.3: Actual and ideal durations of sleep (n=9866) (Source: This Study)

Figures 5.4 and 5.5 show the time Hong Kong people go to sleep and wake up for the primary sleep. It can be seen that in Hong Kong, only a very small proportion (6.6%) go to bed on or before 2100 hour. However, by 2300 hour, more than half of them (54.1%) have gone to sleep, and only 16.8% respondents still stay up at mid-night. In other words, about 30% of the people go to sleep between 2300 hour and mid-night.

Concerning the time people wake up, about one-fourth of the respondents (26.4%) have woken up by 0600 hour, and more than half of the respondents (62.9%) have done so by 0700 hour.

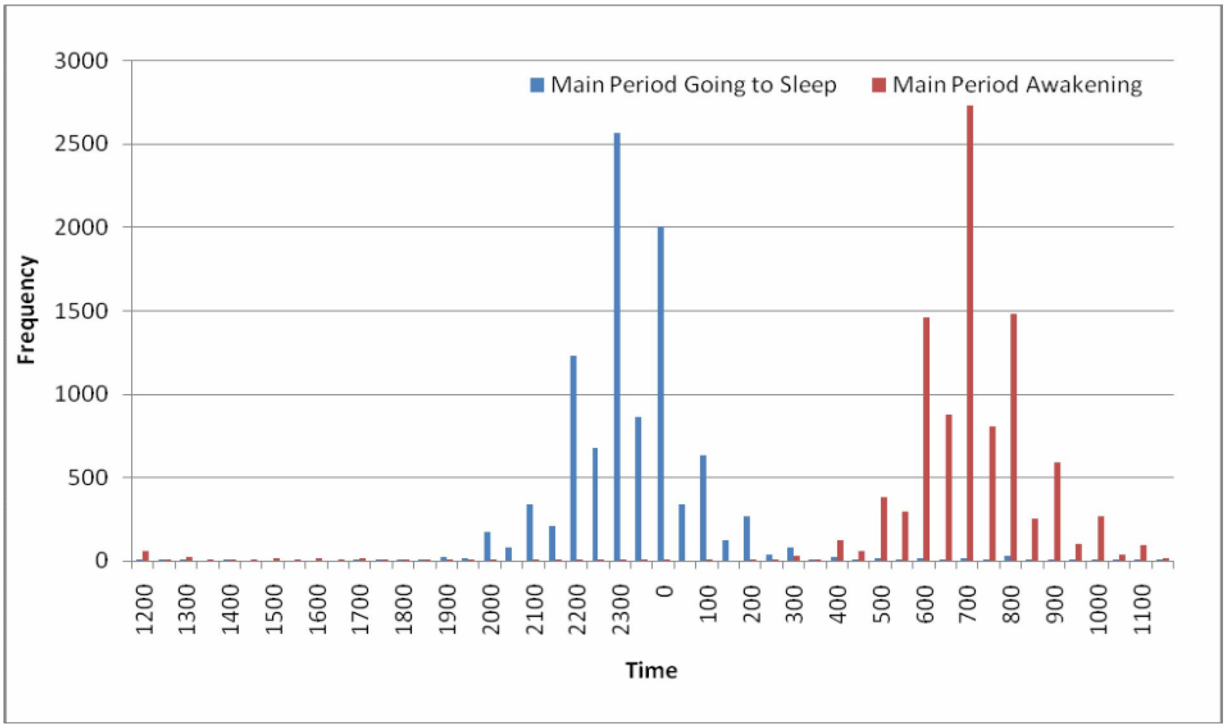

Figure 5.4: Time pattern of going to sleep and awakening for the primary sleep (n=9866) (Source: This Study)

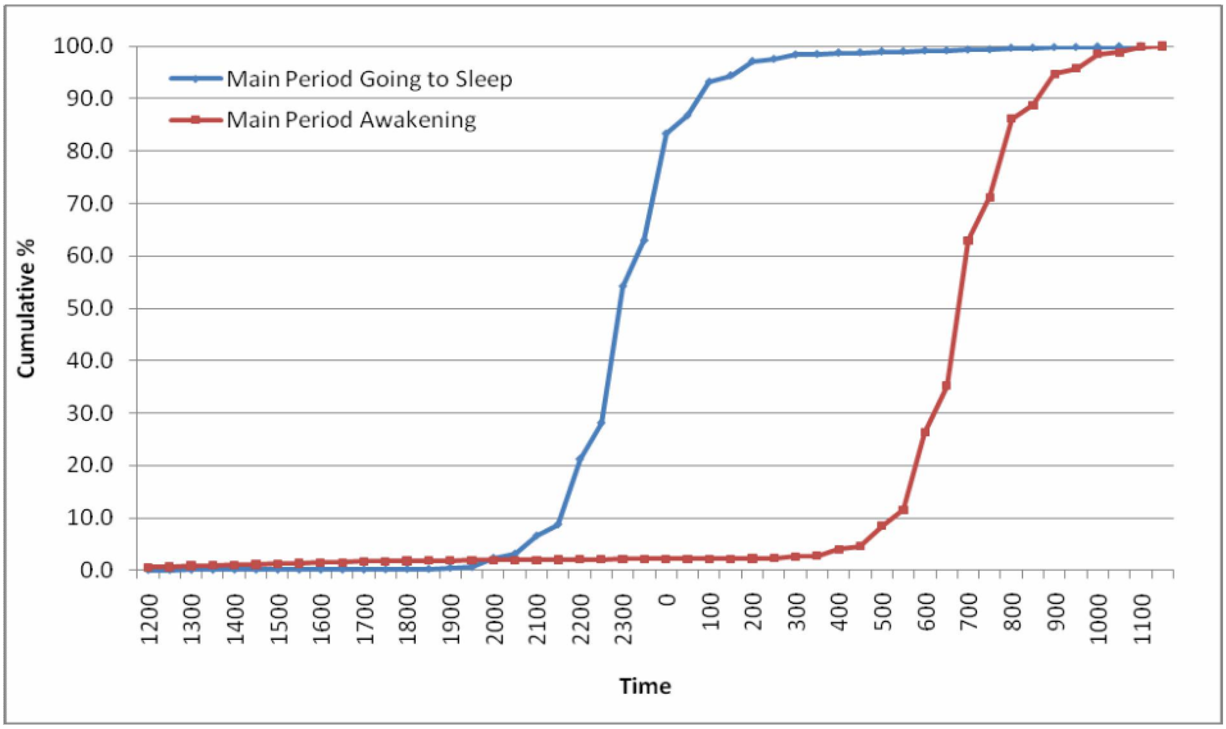

Figure 5.5: Cumulative frequency curves of time pattern of going to sleep and awakening for the primary sleep (n=9866) (Source: This Study)

Figure 5.6 shows the percentage of respondents sleeping at a given time. Most respondents sleep between 2000 hour to 1100 hour.

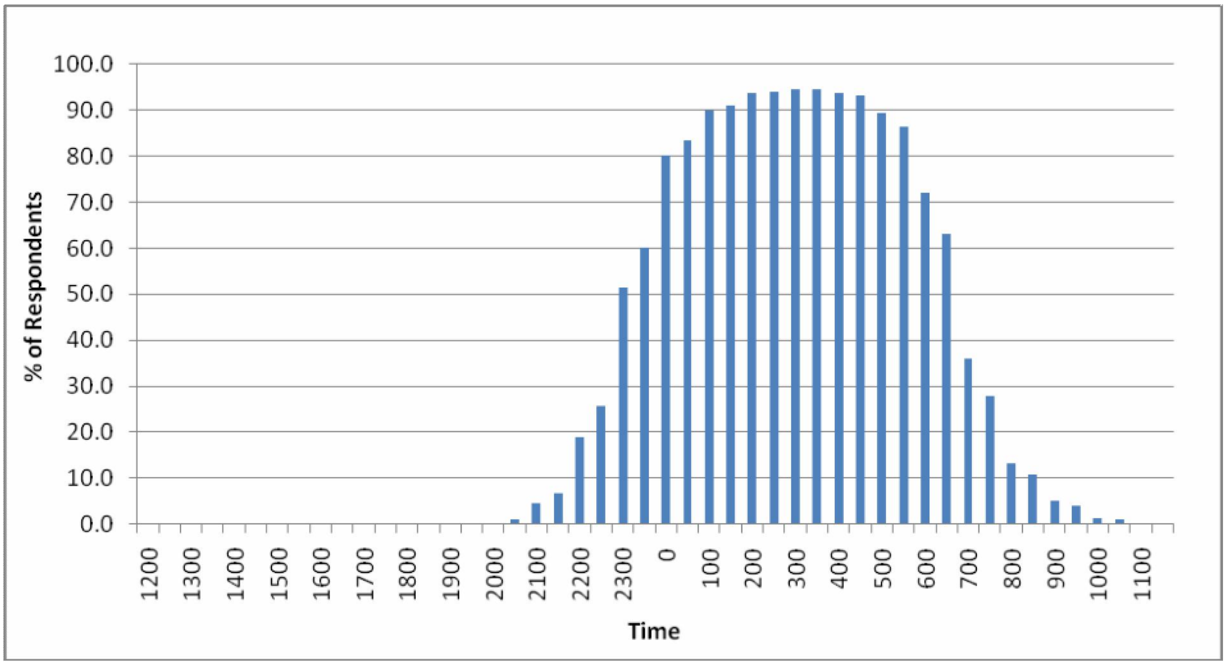

Figure 5.6: Percentages of respondents sleeping at a given time (Source: This Study)

5.3.2 Sleep quality

The sleep quality scale was based on the Groninger sleep quality scale (Meijman et al., 1988) which aims to measure subjective sleep quality in relation to some objective sleep indicators.

The results from this survey are shown in Figure 5.7 and Table 5.5 for Hong Kong as a whole and for public and private housing separately. According to Meijman et al. (1988), scores greater than three can be taken as severe sleep problems. With 30% of respondents assigning themselves with a score of three of above, poor sleep quality is a problem prevalently perceived by Hong Kong people. On the whole, the problem is more severe among residents of public than private housing estates.

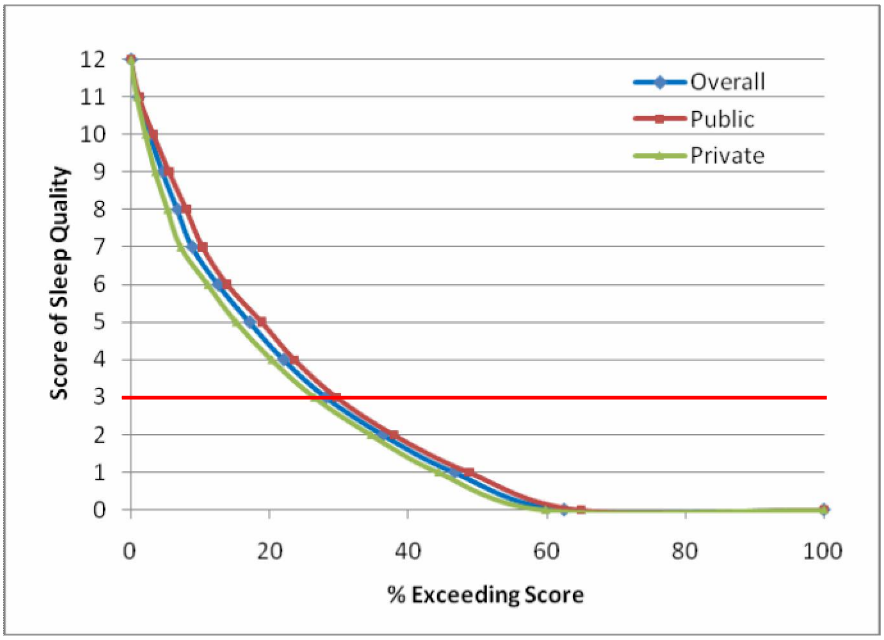

Figure 5.7: Cumulative frequency curves of sleep quality scores (higher scores represent poorer sleep quality) of respondents in public/ private housing (n=10077 with 5244 public and 4833 private) (Source: This Study)

Table 5.5: Distribution of sleep quality scores of respondents in public/ private housing (higher scores represent poorer sleep quality) (Source: This Study)

	Public		Private		All Respondents	
Sleep quality score	n	%	n	%	n	%
0-3	3688	70.3	3554	73.5	7242	71.9
4-6	826	15.8	743	15.4	1569	15.6
7-9	441	8.4	366	7.6	807	8.0
10-12	289	5.5	170	3.5	459	4.6
Total	5244	100.0	4833	100.0	10077	100.0

5.3.3 Sleep disturbance

The possible effects of transportation noise on sleep were evaluation by several questions in the interview. Respondents were asked about their level of annoyance with respect to various noise sources and degree of disturbance to sleep. They were also asked about their level annoyance to particular noise at night and whether their sleep was disturbed at night.

As regards the type of noise which annoy, bother and disturb the sleep of, the residents at night, it can be seen from the results (Figure 5.1 and Table 5.3) that road traffic, neighbors and noise from playgrounds/ sportsgrounds are the top three sources.

Among these three, transportation noise from road traffic ranks top of the list, which can be ascribed to a few factors. The foremost is density. According to the United Nations World Population Prospects Report (2004), Hong Kong ranks the 4th densest region in the world, after Macau, Monaco and Singapore. With over 7 million populations living in an area of 1104 km^2, Hong Kong's density is 6349 persons per km^2, compared to 254.7 persons/km^2 of UK and 32.2 persons/km^2 of USA. High density contributes to proximity of people to noise sources and to their neighbors. Secondly, the urban form also plays a role. Hong Kong has a unique urban layout and building morphology which make some dwellings more exposure to noise from neighbors, playgrounds or motorways (Lam, 2005; Lam, 2009). The effects of urban forms on noise sources and exposure levels are discussed in greater depth in Appendix 7. Finally, the high level of activities almost throughout the whole day is also an important contributor to noise. Located in the sub-tropical region, Hong Kong receives relatively longer daylight throughout the year than the European and North American countries, thus allowing the Hong Kong residents to have long hours of activities extending to late night. These may happen in shops, playgrounds/sports grounds and also at home, causing neighbors and noise from playgrounds/sportsgrounds being the top three noise sources that annoy, bother and disturb the sleep of the residents at night.

Conversely, there are certain activities which have a marked diurnal pattern. They include aircraft, industries, factories and construction/ demolition work. They have received the lowest level of annoyance, among all 11 noise sources surveyed. The study has also substantiated the postulation that the higher the night time annoyance the higher will also be the level of sleep disturbance (Table 5.6). The strong association between annoyance and disturbance at night is well understood. The same phenomenon was observed in a number of previous studies (van Kamp EPD Working Paper, 2010 – Appendix 2; Miedema et al., 2002). The concordance is found not only in road traffic noise which dominates throughout almost the whole day, but also in construction and playground noise which are less noticeable at night.

Table 5.6: Correlation analysis of road traffic, aircraft and neighbors noises on night time annoyance with sleep disturbance on a 0-10 numeric scale (Source: This Study)

n=10077	How much is your sleep disturbed by road traffic noise
How much noise from road traffic bother, disturb, or annoy you **at night**	0.824**
How much noise from aircraft bother, disturb, or annoy you **at night**	0.786**
How much noise from neighbors bother, disturb, or annoy you **at night**	0.725**

**. Correlation is significant at the 0.01 level (2-tailed).

5.4 Self-reported health status, health-related well-being and diseases diagnosed

Health is both an outcome of, and a modifier of annoyance/sleep disturbance arising from, road transportation noise. As previously indicated, this study has not been designed to investigate the diseases caused by transportation noise through clinical investigation. Nonetheless, a few questions had been asked to determine the general health status of the respondent from their personal appraisal. The data so obtained can be used to find out the association between the self-reported health conditions of the respondents and their subjective response to noise.

5.4.1 Self-reported health status

Table 5.7 shows the self-reported health status of all respondents. The majority of respondents reported having fair to very good health. Only 9.2% respondents report a poor to very poor health.

Table 5.7: Health status (Source: This Study)

Health status	n	%
Very good	310	3.1
Good	3996	39.7
Fair	4847	48.1
Poor	863	8.6
Very poor	61	0.6
Total	10077	3.1

As regards the trend of their health status, the findings (Table 5.8) show most of the respondents thought their health conditions remained about the same as compared to that a year ago. Only less than 20% respondents reported that their health is somewhat or much worse than one year ago.

Table 5.8: Current health status compared to one year ago (Source: This Study)

Health status compared to one year ago	n	%
Much better than a year ago	45	0.4
Somewhat better than a year ago	632	6.3
About the same now as a year ago	7621	75.6
Somewhat worse than a year ago	1699	16.9
Much worse than a year ago	80	0.8
Total	10077	100.0

5.4.2 Health-related quality of life

Asking whether the respondent had consulted a general practitioner (GP) or local doctor about health in the last two weeks, the results (Table 5.9) indicate that majority of the respondents had not consulted a GP or local doctor about their health in the two weeks prior to the interview. About 20% respondents had done so. Likewise, only 10% of the respondents had been hospitalized in the preceding two years (Table 5.10).

Table 5.9: Consulted a GP or local doctor about respondent’s health in the last two weeks (Source: This Study)

Consulted a GP or local doctor about respondent’s health in the last two weeks	n	%
No	8093	80.3
Yes	1984	19.7
Total	10077	100.0

Table 5.10: Whether the respondent was hospitalized in the past two years (Source: This Study)

Hospitalized in the past two years	n	%
No	9045	89.8
Yes	1032	10.2
Total	10077	100.0

5.4.3 Diagnosed diseases which may be related to noise/ annoyance

Table 5.11 shows whether the respondent has been diagnosed with, and treated for, a number of diseases in the past one month. Among all types of diseases asked, hypertension and diabetes are two most commonly diagnosed by a doctor.

The results in Table 5.11 show that only a small percentage had been diagnosed with insomnia and depression/anxiety which are thought to be related to sleep disorder and noise sensitivity. Those who have diagnosed with insomnia and depression/ anxiety tend to be undertreated as compared to other diseases such as hypertension and diabetes. Furthermore, very few have sleeping pills and tranquilizers in spite of the diagnosis.

Table 5.11: Whether the respondent has been diagnosed with different diseases and regularly treated for a particular disease in the past one month (Source: This Study)

		Diagnosed		Treated		
		n	%		n	%
Hypertension	No	8557	84.9			
	Yes	1520	15.1	No	139	9.1
				Yes	1381	90.9
				Total	1520	100.0
	Total	10077	100.0			
Heart disease/ cardiovascular effects	No	9711	96.4			
	Yes	366	3.6	No	63	17.2
				Yes	303	82.8
				Total	366	100.0
	Total	10077	100.0			
Diabetes	No	9579	95.1			
	Yes	498	4.9	No	41	8.2
				Yes	457	91.8
				Total	498	100.0
	Total	10077	100.0			
Chronic headaches/ migraines	No	9938	98.6			
	Yes	139	1.4	No	53	38.1
				Yes	86	61.9
				Total	139	100.0
	Total	10077	100.0			
Depression/ anxiety	No	9917	98.4			
	Yes	160	1.6	No	48	30.0
				Yes	112	70.0
				Total	160	100.0
	Total	10077	100.0			
Insomnia (severe sleeping problems)	No	9940	98.6			
	Yes	137	1.4	No	57	41.6
				Yes	80	58.4
				Total	137	100.0
	Total	10077	100.0			
Peptic ulcer	No	9943	98.7			
	Yes	134	1.3	No	61	45.5
				Yes	73	54.5
				Total	134	100.0
	Total	10077	100.0			
Asthma	No	9931	98.6			
	Yes	146	1.4	No	53	36.3
				Yes	93	63.7
				Total	146	100.0
	Total	10077	100.0			

Table 5.12 shows the percentage of respondents who used medication in the past one month and the frequency of drug taking. Medication for hypertension, cardiovascular disease and diabetes are of the three drugs most frequently reported by the respondents who had been diagnosed with the corresponding diseases in the past one month. Within this group, 95% of respondents regularly take these medications once a day or more.

Conversely, sleeping pills and tranquilizers are taken relatively less frequently, despite the diagnosis, as compared anti-hypertension and medication for cardiovascular disease.

Table 5.12: Percentage and frequency of medication use in the past one month
(Source: This Study)

Drug Taken in the Past One Month				Frequency		
		n	%		n	%
Hypertension Drugs	No	8681	86.1			
	Yes	1396	13.9	Once a day or more often	1365	97.8
				More than once a week but not daily	26	1.9
				Once a week	4	0.3
				More than once a month but less than once a week	0	0.0
				Once a month	1	0.1
				Less than once a month	0	0.0
				Total	1396	100.0
	Total	10077	100.0			
Cardiovascular Drugs	No	9765	96.9			
	Yes	312	3.1	Once a day or more often	298	95.5
				More than once a week but not daily	8	2.6
				Once a week	1	0.3
				More than once a month but less than once a week	0	0.0
				Once a month	1	0.3
				Less than once a month	4	1.3
				Total	312	100.0
	Total	10077	100.0			
Anti-diabetic Drugs	No	9628	95.5			
	Yes	449	4.5	Once a day or more often	440	98.0
				More than once a week but not daily	9	2.0
				Once a week	0	0
				More than once a month but less than once a week	0	0
				Once a month	0	0
				Less than once a month	0	0
				Total	449	100.0
	Total	10077	100.0			
Sleeping Pills	No	9984	99.1			
	Yes	93	0.9	Once a day or more often	47	50.5
				More than once a week but not daily	16	17.2
				Once a week	7	7.5
				More than once a month but less than once a week	11	11.8
				Once a month	4	4.3
				Less than once a month	8	8.6
				Total	93	100.0
	Total	10077	100.0			

Drug Taken in the Past One Month				Frequency		
		n	%		n	%
Tranquilizer	No	9986	99.1			
	Yes	91	0.9	Once a day or more often	69	75.8
				More than once a week but not daily	13	14.3
				Once a week	3	3.3
				More than once a month but less than once a week	1	1.1
				Once a month	1	1.1
				Less than once a month	4	4.4
				Total	91	100.0
	Total	10077	100.0			

To explore possible relationship between diseases and those who reported being highly annoyed throughout the day, highly annoyed at night and highly sleep disturbed, the respondents' report on diseases diagnosed and treatments received are given in Tables 5.13, 5.14 and 5.15 respectively. As indicated previously, a highly annoyed or highly disturbed response refers to one which falls within the 8-10 range on the 0-10 scale.

To ascertain whether people who are highly annoyed/ disturbed by a certain noise source are significantly different from those who are not, the percentages of people diagnosed with some common diseases of the two groups and their respective total sample sizes are compared using the F-test in Tables 5.13, 5.14 and 5.15. The results show that for all three types of responses (annoyance throughout the day, annoyance at night and sleep disturbance), those who are highly annoyed/ disturbed are more likely to have chronic headache, anxiety and insomnia conditions. However, it should be cautiously noted that such an association does not say whether the disease is the outcome of noise exposure, or the annoyance and sleep disturbance feelings are the outcome of the disease. No significant between-group difference was found in the incidence of hypertension and heart disease. More data has to be collected to elucidate the complex relationship between self-reported annoyance reactions and clinical conditions.

In addition, an investigation has also been undertaken to unravel any association between the self-rated sleep quality and the incidence of a number of diseases. The respondents are divided into two groups (Table 5.16); those who report a score between 10 and 12 are deemed to have much poorer sleep quality than the others. The results show that for those who claimed having poorer sleep quality are more likely to suffer from hypertension and insomnia.

Table 5.13: Distribution of respondents **highly annoyed** and those who have been diagnosed with different diseases and taking medication (Source: This Study)

		All		Highly Annoyed (HA)					Non-highly Annoyed (non-HA)					Difference between HA & non-HA by F-test*
		Diagnosed		Diagnosed		Treated			Diagnosed		Treated			
Disease		n	%	n	%		n	%	n	%		n	%	
Hypertension	No	8557	84.9	623	83.0				7934	85.1				F=2.434 (ns)
	Yes	1520	15.1	128	**17.0**	No	15	11.7	1392	**14.9**	No	124	8.9	
						Yes	113	88.3			Yes	1268	91.1	
						Total	128	100.0			Total	1392	100.0	
	Total	10077	100.0	751	100.0				9326	100.0				
Heart disease/ cardiovascular effects	No	9711	96.4	716	95.3				8995	96.5				F=2.452 (ns)
	Yes	366	3.6	35	4.7	No	9	25.7	331	3.5	No	54	16.3	
						Yes	26	74.3			Yes	277	83.7	
						Total	35	100.0			Total	331	100.0	
	Total	10077	100.0	751	100.0				9326	100.0				
Diabetes	No	9579	95.1	700	93.2				8879	95.2				F=5.908 (0.05)
	Yes	498	4.9	51	**6.8**	No	5	9.8	447	**4.8**	No	36	8.1	
						Yes	46	90.2			Yes	411	91.9	
						Total	51	100.0			Total	447	100.0	
	Total	10077	100.0	751	100.0				9326	100.0				
Chronic headaches/ migraines	No	9938	98.6	732	97.5				9206	98.7				F=7.902 (<0.01)
	Yes	139	1.4	19	2.5	No	3	15.8	120	1.3	No	50	41.7	
						Yes	16	84.2			Yes	70	58.3	
						Total	19	100.0			Total	120	100.0	
	Total	10077	100.0	751	100.0				9326	100.0				
Depression/ anxiety	No	9917	98.4	728	96.9				9189	98.5				F=11.306 (<0.01)
	Yes	160	1.6	23	**3.1**	No	4	17.4	137	**1.5**	No	44	32.1	
						Yes	19	82.6			Yes	93	67.9	
						Total	23	100.0			Total	137	100.0	
	Total	10077	100.0	751	100.0				9326	100.0				
Insomnia (severe sleeping problems)	No	9940	98.6	727	96.8				9213	98.8				F=20.439 (<0.01)
	Yes	137	1.4	24	**3.2**	No	4	16.7	113	**1.2**	No	53	46.9	
						Yes	20	83.3			Yes	60	53.1	
						Total	24	100.0			Total	113	100.0	
	Total	10077	100.0	751	100.0				9326	100.0				
Peptic ulcer	No	9943	98.7	731	97.3				9212	98.8				F=11.005 (<0.01)
	Yes	134	1.3	20	2.7	No	8	40.0	114	1.2	No	53	46.5	
						Yes	12	60.0			Yes	61	53.5	
						Total	20	100.0			Total	114	100.0	
	Total	10077	100.0	751	100.0				9326	100.0				
Asthma	No	9931	98.6	731	97.3				9200	98.6				F=8.385 (<0.01)
	Yes	146	1.4	20	2.7	No	10	50.0	126	1.4	No	43	34.1	
						Yes	10	50.0			Yes	83	65.9	
						Total	20	100.0			Total	126	100.0	
	Total	10077	100.0	751	100.0				9326	100.0				

*"ns" means that the named disease between highly annoyed and non-highly annoyed group is statistically insignificant.

Table 5.14: Distribution of respondents **highly annoyed at night** and those who have been diagnosed with different diseases and taking medication (Source: This Study)

	All			Highly Annoyed at Night (HAN)					Non-highly Annoyed at Night (non-HAN)					Difference between HAN & non-HAN by F-test*
	Diagnosed			Diagnosed		Treated			Diagnosed		Treated			
Disease		n	%	n	%		n	%	n	%		n	%	
Hypertension	No	8557	84.9	399	84.2				8158	85.0				F=0.212 (ns)
	Yes	1520	15.1	75	**15.8**	No	10	13.3	1445	**15.0**	No	129	8.9	
						Yes	65	86.7			Yes	1316	91.1	
						Total	75	100.0			Total	1445	100.0	
	Total	10077	100.0	474	100.0				9603	100.0				
Heart disease/ cardiovascular effects	No	9711	96.4	453	95.6				9258	96.4				F=0.906 (ns)
	Yes	366	3.6	21	4.4	No	7	33.3	345	3.6	No	56	16.2	
						Yes	14	66.7			Yes	289	83.8	
						Total	21	100.0			Total	345	100.0	
	Total	10077	100.0	474	100.0				9603	100.0				
Diabetes	No	9579	95.1	449	94.7				9130	95.1				F=0.117 (ns)
	Yes	498	4.9	25	**5.3**	No	3	12.0	473	**4.9**	No	38	8.0	
						Yes	22	88.0			Yes	435	92.0	
						Total	25	100.0			Total	473	100.0	
	Total	10077	100.0	474	100.0				9603	100.0				
Chronic headaches/ migraines	No	9938	98.6	455	96.0				9483	98.8				F=25.33 (<0.01)
	Yes	139	1.4	19	4.0	No	5	26.3	120	1.2	No	48	40.0	
						Yes	14	73.7			Yes	72	60.0	
						Total	19	100.0			Total	120	100.0	
	Total	10077	100.0	474	100.0				9603	100.0				
Depression/ anxiety	No	9917	98.4	457	96.4				9460	98.5				F=12.730 (<0.01)
	Yes	160	1.6	17	**3.6**	No	4	23.5	143	**1.5**	No	44	30.8	
						Yes	13	76.5			Yes	99	69.2	
						Total	17	100.0			Total	143	100.0	
	Total	10077	100.0	474	100.0				9603	100.0				
Insomnia (severe sleeping problems)	No	9940	98.6	455	96.0				9485	98.8				F=26.087 (<0.01)
	Yes	137	1.4	19	**4.0**	No	4	21.1	118	**1.2**	No	53	44.9	
						Yes	15	78.9			Yes	65	55.1	
						Total	19	100.0			Total	118	100.0	
	Total	10077	100.0	474	100.0				9603	100.0				
Peptic ulcer	No	9943	98.7	458	96.6				9485	98.8				F=15.887 (<0.01)
	Yes	134	1.3	16	3.4	No	7	43.8	118	1.2	No	54	45.8	
						Yes	9	56.3			Yes	64	54.2	
						Total	16	100.0			Total	118	100.0	
	Total	10077	100.0	474	100.0				9603	100.0				
Asthma	No	9931	98.6	462	97.5				9469	98.6				F=4.085 (<0.01)
	Yes	146	1.4	12	2.5	No	8	66.7	134	1.4	No	45	33.6	
						Yes	4	33.3			Yes	89	66.4	
						Total	12	100.0			Total	134	100.0	
	Total	10077	100.0	474	100.0				9603	100.0				

*"ns" means that the named disease between highly annoyed at night and non-highly annoyed at night group is statistically insignificant.

Table 5.15: Distribution of respondents **highly sleep disturbed** and those who have been diagnosed with different diseases and taking medication (Source: This Study)

	All			Highly Sleep Disturbed (HSD)					Non-highly Sleep Disturbed (non-HSD)					Difference between HSD & non-HSD by F-test*
	Diagnosed			Diagnosed		Treated			Diagnosed		Treated			
Disease		n	%	n	%		n	%	n	%		n	%	
Hypertension	No	8557	84.9	338	84.7				8219	84.9				F=0.014 (ns)
	Yes	1520	15.1	61	**15.3**	No	11	18.0	1459	**15.1**	No	128	8.8	
						Yes	50	82.0			Yes	1331	91.2	
						Total	61	100.0			Total	1459	100.0	
	Total	10077	100.0	399	100.0				9678	100.0				
Heart disease/ cardiovascular effects	No	9711	96.4	381	95.5				9330	96.4				F=0.918 (ns)
	Yes	366	3.6	18	4.5	No	7	38.9	348	3.6	No	56	16.1	
						Yes	11	61.1			Yes	292	83.9	
						Total	18	100.0			Total	348	100.0	
	Total	10077	100.0	399	100.0				9678	100.0				
Diabetes	No	9579	95.1	375	94.0				9204	95.1				F=1.018 (ns)
	Yes	498	4.9	24	**6.0**	No	3	12.5	474	**4.9**	No	38	8.0	
						Yes	21	87.5			Yes	436	92.0	
						Total	24	100.0			Total	474	100.0	
	Total	10077	100.0	399	100.0				9678	100.0				
Chronic headaches/ migraines	No	9938	98.6	383	96.0				9555	98.7				F=21.175 (<0.01)
	Yes	139	1.4	16	4.0	No	6	37.5	123	1.3	No	47	38.2	
						Yes	10	62.5			Yes	76	61.8	
						Total	16	100.0			Total	123	100.0	
	Total	10077	100.0	399	100.0				9678	100.0				
Depression/ anxiety	No	9917	98.4	381	95.5				9536	98.5				F=22.771 (<0.01)
	Yes	160	1.6	18	**4.5**	No	6	33.3	142	**1.5**	No	42	29.6	
						Yes	12	66.7			Yes	100	70.4	
						Total	18	100.0			Total	142	100.0	
	Total	10077	100.0	399	100.0				9678	100.0				
Insomnia (severe sleeping problems)	No	9940	98.6	381	95.5				9559	98.8				F=30.862 (<0.01)
	Yes	137	1.4	18	**4.5**	No	4	22.2	119	**1.2**	No	53	44.5	
						Yes	14	77.8			Yes	66	55.5	
						Total	18	100.0			Total	119	100.0	
	Total	10077	100.0	399	100.0				9678	100.0				
Peptic ulcer	No	9943	98.7	385	96.5				9558	98.8				F=15.054 (<0.01)
	Yes	134	1.3	14	3.5	No	5	35.7	120	1.2	No	56	46.7	
						Yes	9	64.3			Yes	64	53.3	
						Total	14	100.0			Total	120	100.0	
	Total	10077	100.0	399	100.0				9678	100.0				
Asthma	No	9931	98.6	390	97.7				9541	98.6				F=1.894 (ns)
	Yes	146	1.4	9	2.3	No	4	44.4	137	1.4	No	49	35.8	
						Yes	5	55.6			Yes	88	64.2	
						Total	9	100.0			Total	137	100.0	
	Total	10077	100.0	399	100.0				9678	100.0				

*"ns" means that the named disease between highly sleep disturbed and non-highly sleep disturbed group is statistically insignificant.

Table 5.16: Distribution of respondents with sleep quality scores (10-12) (worst 25%) and those who have been diagnosed with different diseases and taking medication (Source: This Study)

		All		Sleep Quality Score (10-12) = Worst 25%					Sleep Quality Score (0-9) = Other 75%					Difference between worst 25% & others by F-test*
		Diagnosed		Diagnosed		Treated			Diagnosed		Treated			
Disease		n	%	n	%		n	%	n	%		n	%	
Hypertension	No	8557	84.9	326	71.0				8231	85.6				F=13.634 (<0.01)
	Yes	1520	15.1	133	**29.0**	No	13	9.8	1387	**14.4**	No	126	9.1	
						Yes	120	90.2			Yes	1261	90.9	
						Total	133	100.0			Total	1387	100.0	
	Total	10077	100.0	459	100.0				9618	100.0				
Heart disease/ cardiovascular effects	No	9711	96.4	416	90.6				9295	96.6				F=5.904 (<0.01)
	Yes	366	3.6	43	9.4	No	7	16.3	323	3.4	No	56	17.3	
						Yes	36	83.7			Yes	267	82.7	
						Total	43	100.0			Total	323	100.0	
	Total	10077	100.0	459	100.0				9618	100.0				
Diabetes	No	9579	95.1	411	89.5				9168	95.3				F=6.865 <0.01
	Yes	498	4.9	48	10.5	No	8	16.7	450	**4.7**	No	33	7.3	
						Yes	40	83.3			Yes	417	92.7	
						Total	48	100.0			Total	450	100.0	
	Total	10077	100.0	459	100.0				9618	100.0				
Chronic headaches/ migraines	No	9938	98.6	425	92.6				9513	98.9				F=20.524 <0.01
	Yes	139	1.4	34	7.4	No	10	29.4	105	1.1	No	43	41.0	
						Yes	24	70.6			Yes	62	59.0	
						Total	34	100.0			Total	105	100.0	
	Total	10077	100.0	459	100.0				9618	100.0				
Depression/ anxiety	No	9917	98.4	428	93.2				9489	98.7				F=15.682 <0.01
	Yes	160	1.6	31	**6.8**	No	11	35.5	129	**1.3**	No	37	28.7	
						Yes	20	64.5			Yes	92	71.3	
						Total	31	100.0			Total	129	100.0	
	Total	10077	100.0	459	100.0				9618	100.0				
Insomnia (severe sleeping problems)	No	9940	98.6	399	86.9				9541	99.2				F=60.441 <0.01
	Yes	137	1.4	60	**13.1**	No	29	48.3	77	**0.8**	No	28	36.4	
						Yes	31	51.7			Yes	49	63.6	
						Total	60	100.0			Total	77	100.0	
	Total	10077	100.0	459	100.0				9618	100.0				
Peptic ulcer	No	9943	98.7	436	95.0				9507	98.8				F=6.792 <0.01
	Yes	134	1.3	23	5.0	No	8	34.8	111	1.2	No	53	47.7	
						Yes	15	65.2			Yes	58	52.3	
						Total	23	100.0			Total	111	100.0	
	Total	10077	100.0	459	100.0				9618	100.0				
Asthma	No	9931	98.6	444	96.7				9487	98.6				F=3.160 (<0.01)
	Yes	146	1.4	15	3.3	No	3	20.0	131	1.4	No	50	38.2	
						Yes	12	80.0			Yes	81	61.8	
						Total	15	100.0			Total	131	100.0	
	Total	10077	100.0	459	100.0				9618	100.0				

*"ns" means that the named disease between worst 25% sleep quality and others is statistically insignificant.

Chapter Six: Findings: Effects of transportation noise on human annoyance and sleep disturbance in Hong Kong

The primary objective of this study is to ascertain the effects of transportation, particularly road traffic, noise in Hong Kong with particular respect to annoyance and sleep disturbance. In environmental terms, this is an exposure-effect study. Exposure refers to the level of road traffic noise, and effects refer to human response in terms of annoyance and sleep disturbance. Noise exposure estimates, as described above, were obtained by a territory-wide noise mapping exercise. This section begins with a description of the exposure of the Hong Kong population to road traffic noise; explains how the best fitting exposure-effect curve was obtained; compares the curve of Hong Kong with similar curves obtained elsewhere; elucidates the factors affecting human annoyance response and sleep disturbance, and finally discusses the significance of the findings.

6.1 Exposure of the Hong Kong population to road traffic noise

Using the noise mapping technique undertaken separately by EPD and described in section 2.3, the exposure of the Hong Kong population to road traffic noise in 2010 was obtained. It should be noted that these estimates were obtained from a quasi-random sample of the entire Hong Kong population, using a method which may be different from some previous studies based on stratified sampling, or which targeting only parts of the cities abutting major roadways. In this study, the sample covered the whole of Hong Kong, irrespective of whether it is urban or rural, city or countryside. Any comparison of data should take this into consideration.

The noise metrics of the current study include $L_{10,\,1h\,a.m.}$, $L_{10,\,1h,\,p.m.}$, L_{DEN}, L_{DAY}, $L_{EVENING}$, and L_{NIGHT}. The first two metrics, based on $L_{10,\,1h}$, have been used for many years in Hong Kong following the convention in the UK. The latter four are now widely used in EU and other countries. Of these four, L_{DEN} and L_{NIGHT} are most commonly used metrics. A correlation analysis (Table 6.1) shows that these 6 metrics are inter-correlated. $L_{10,\,1h\,a.m.}$ and $L_{10,\,1h,\,p.m.}$ are particularly closely related to L_{DAY}.

Table 6.1: Correlation matrix of six noise metrics (Source: This Study)

	L_{DEN}	L_{DAY}	$L_{EVENING}$	L_{NIGHT}	$L_{10,\,1h\,AM}$	$L_{10\,1h,\,PM}$
L_{DEN}						
L_{DAY}	0.996**					
$L_{EVENING}$	0.999**	0.998**				
L_{NIGHT}	0.997**	0.986**	0.993**			
$L_{10,\,1h\,AM}$	0.905**	0.909**	0.905**	0.897**		
$L_{10\,1h,\,PM}$	0.905**	0.908**	0.904**	0.897**	0.997**	

**. Correlation is significant at the 0.01 level (2-tailed).

Figures 6.1 to 6.6 show the distribution of the estimates of these six noise metrics and the curves all resemble the normal distribution. The same data are also presented in the form of cumulative frequency curves (Figures 6.7 to 6.12). It can be seen that 28.9% and 26.0% of the dwellings in the a.m. and p.m. respectively is exposed $L_{10,\ 1h}$ 70 dBA or more on the **most exposed side of the dwelling**. These proportions appear to be higher than the figure of 18% previously estimated for Hong Kong (EPD, 2006). As earlier said, these figures are strictly speaking not directly comparable because of the difference in time and method in noise exposure estimation.

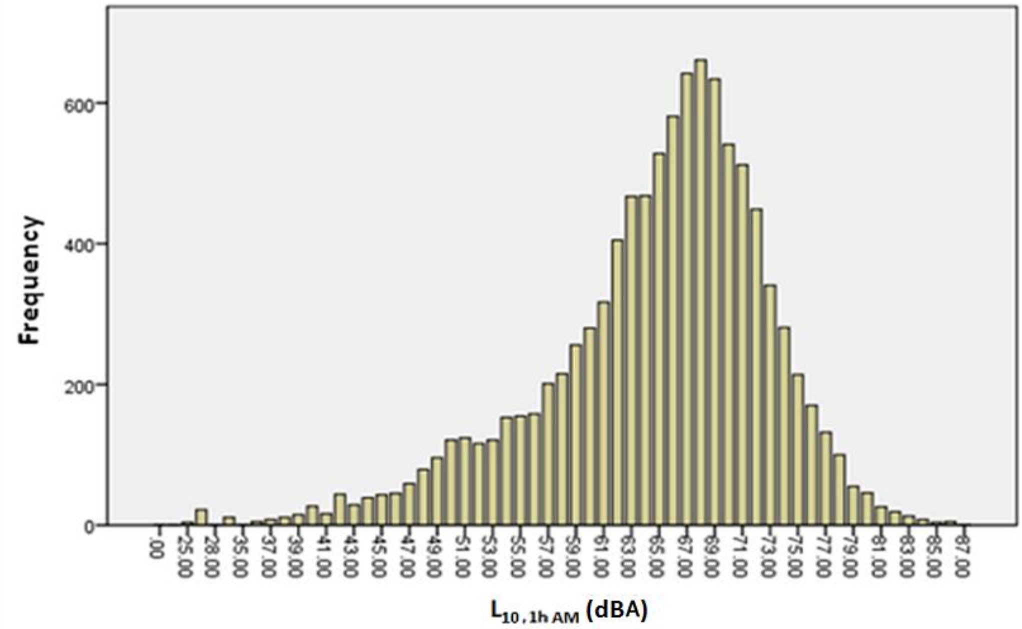

Figure 6.1: $L_{10,\ 1h\ AM}$ distribution (Source: This Study)

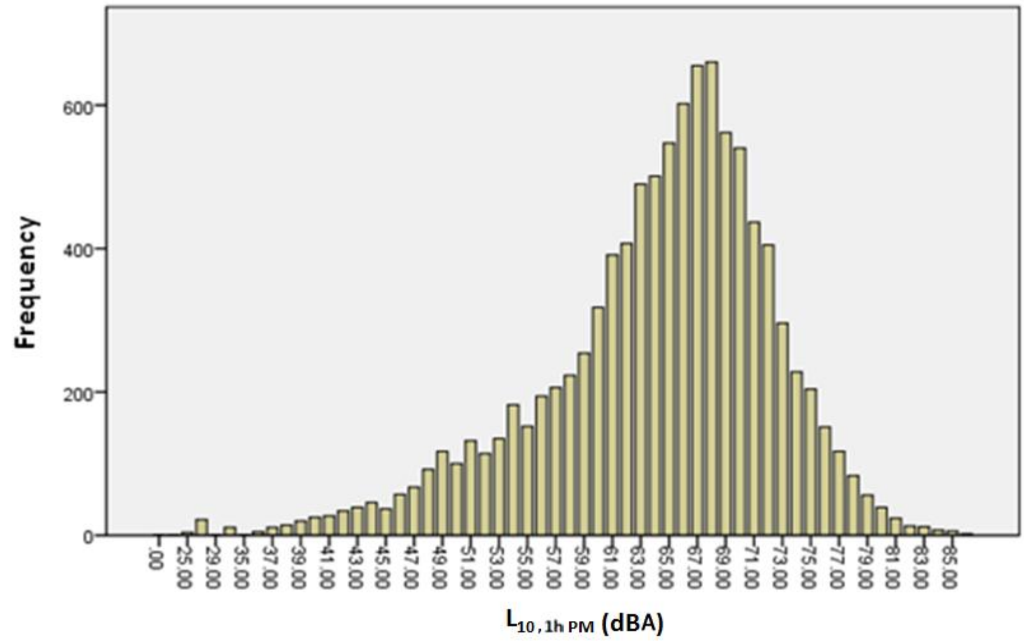

Figure 6.2: $L_{10\ 1h,\ PM}$ distribution (Source: This Study)

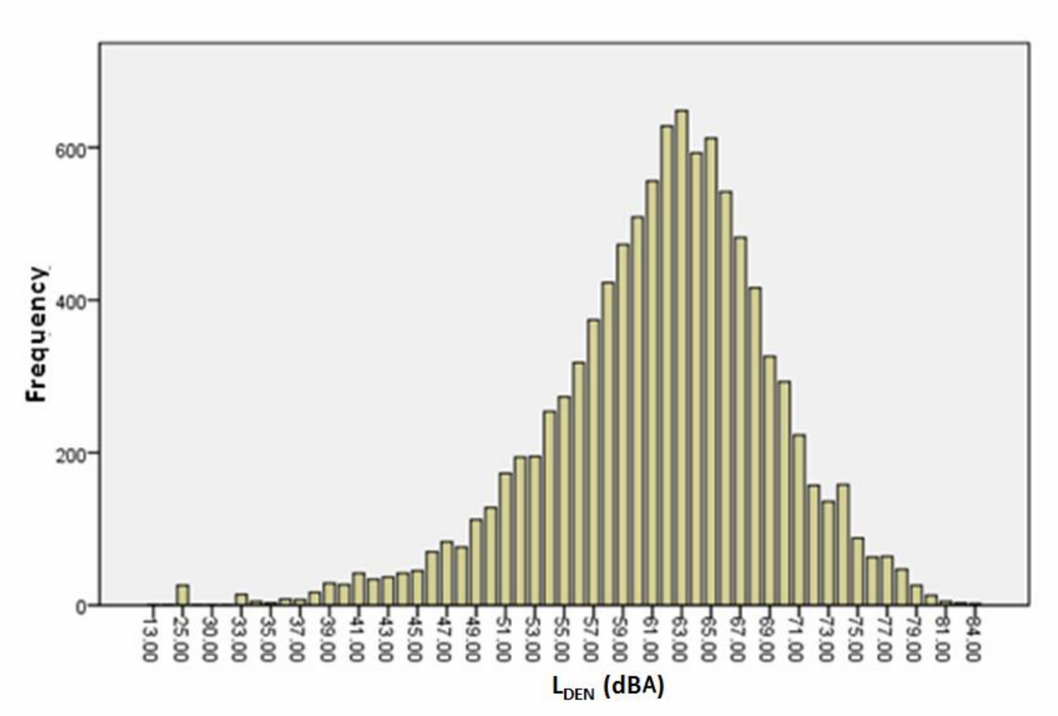

Figure 6.3: L_{DEN} distribution (Source: This Study)

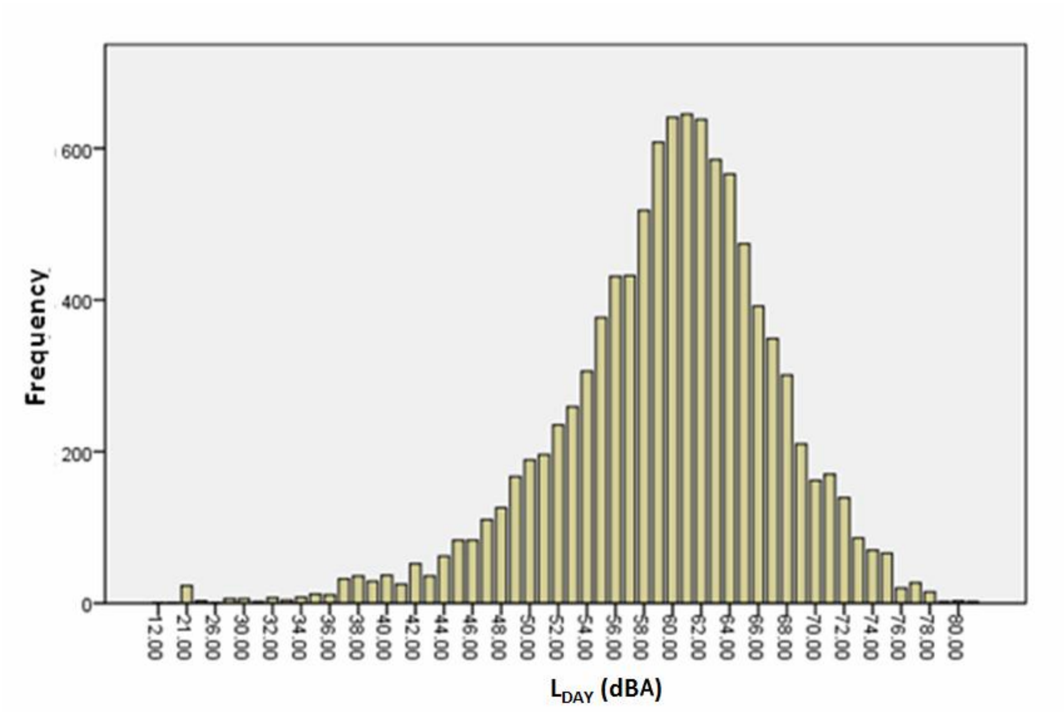

Figure 6.4: L_{DAY} distribution (Source: This Study)

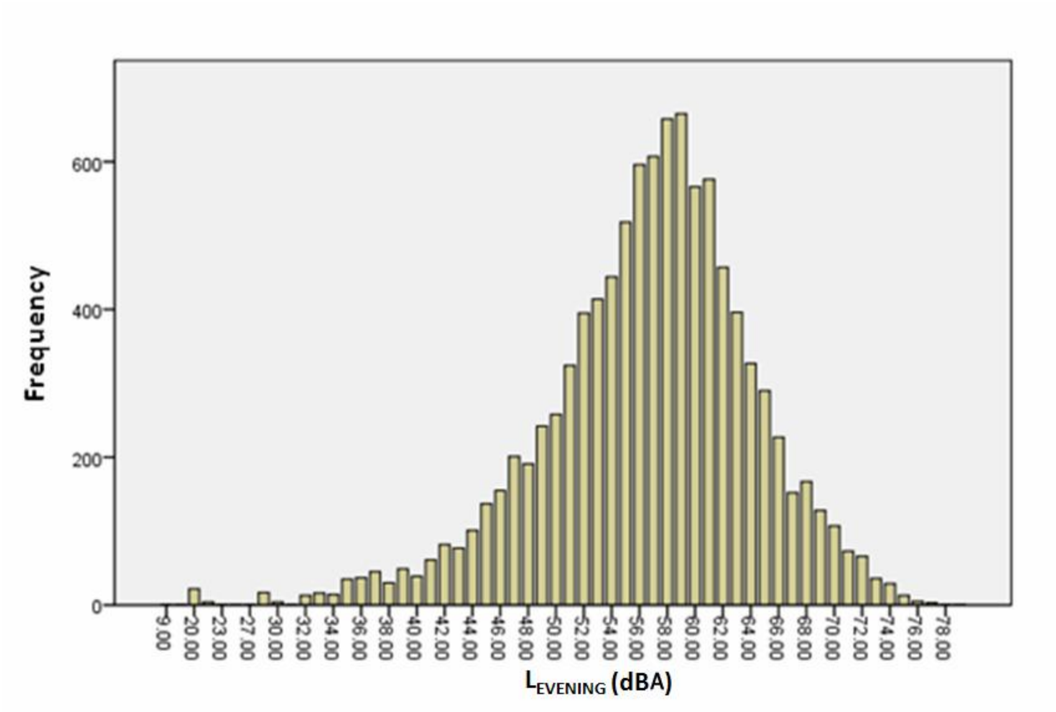

Figure 6.5: $L_{EVENING}$ distribution (Source: This Study)

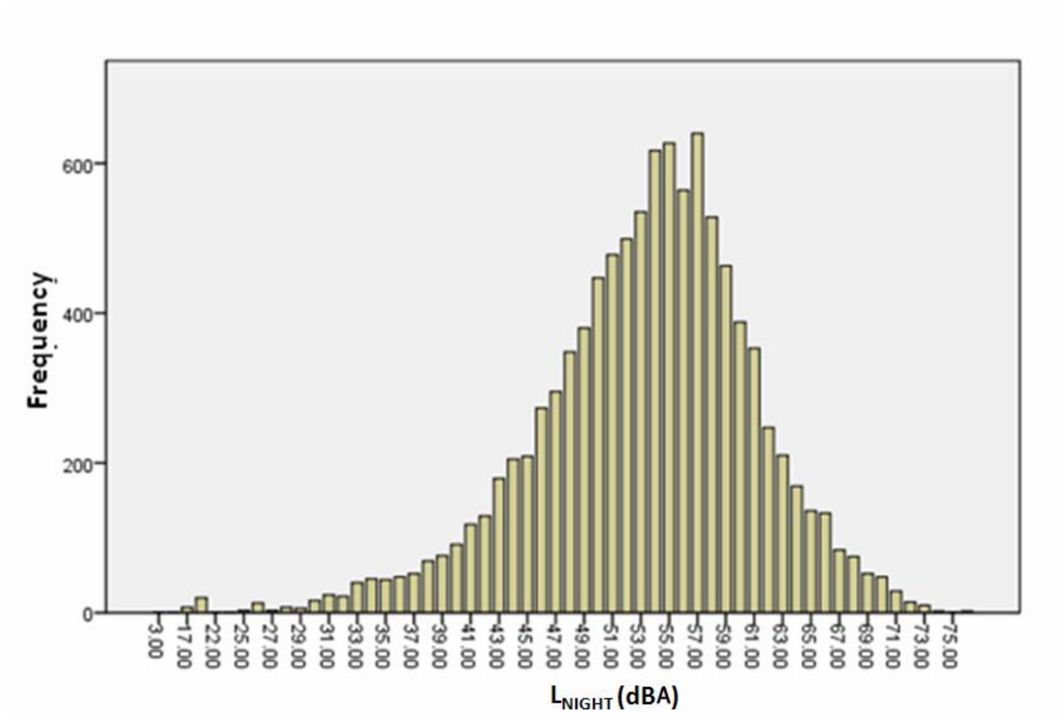

Figure 6.6: L_{NIGHT} distribution (Source: This Study)

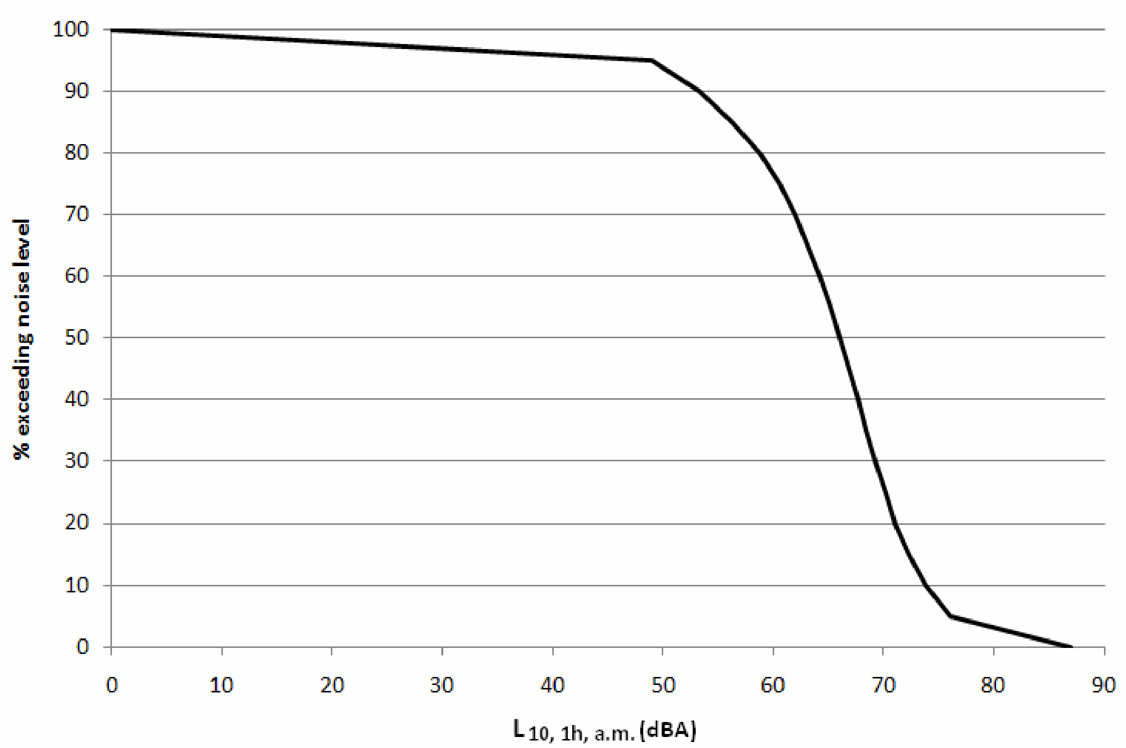

Figure 6.7: Cumulative frequency curve for L_{10AM} (Source: This Study)

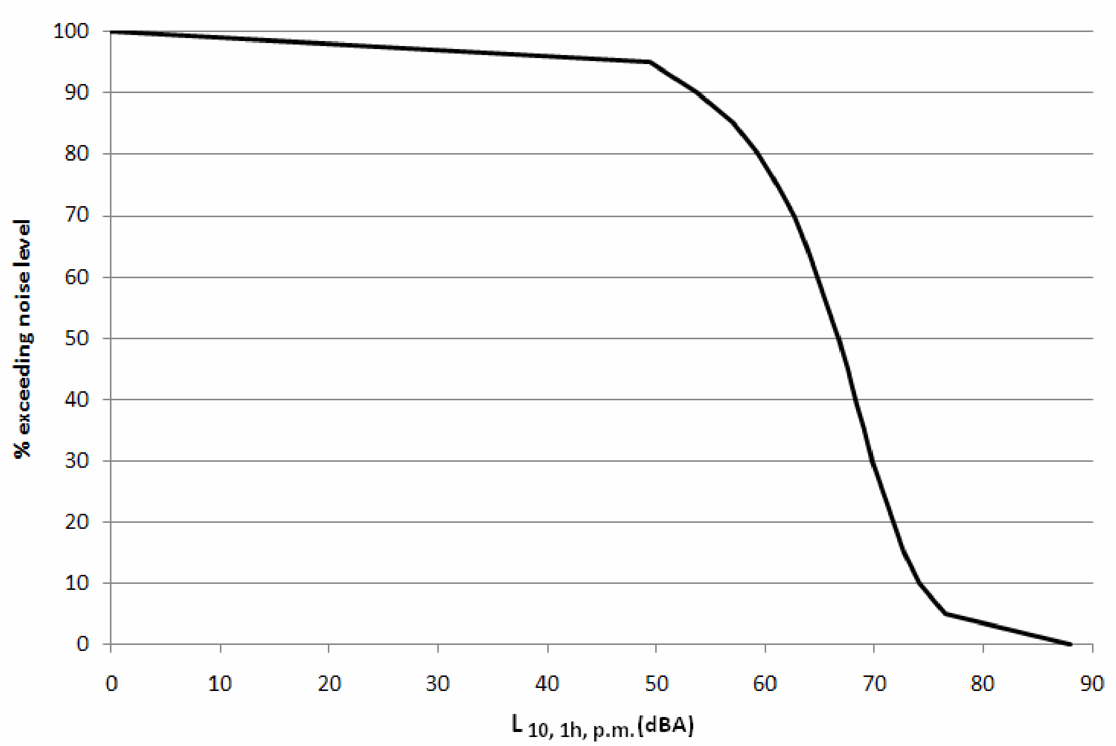

Figure 6.8: Cumulative frequency curve for L_{10PM} (Source: This Study)

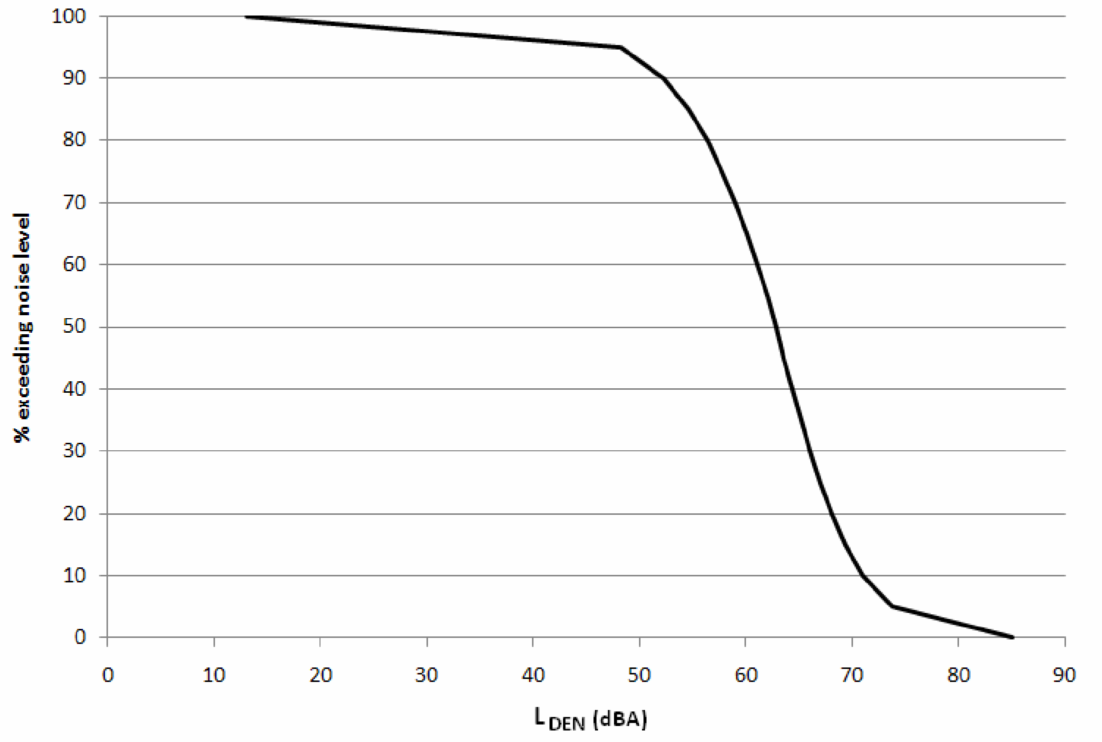

Figure 6.9: Cumulative frequency curve for L_{DEN} (Source: This Study)

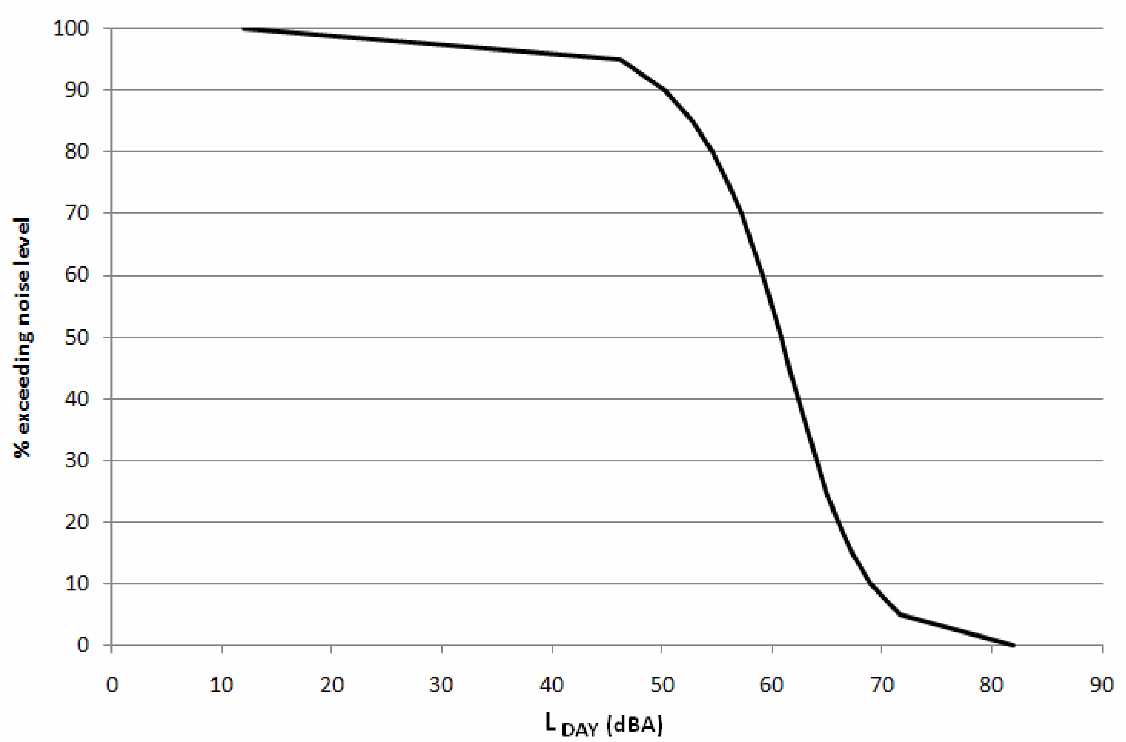

Figure 6.10: Cumulative frequency curve for L_{DAY} (Source: This Study)

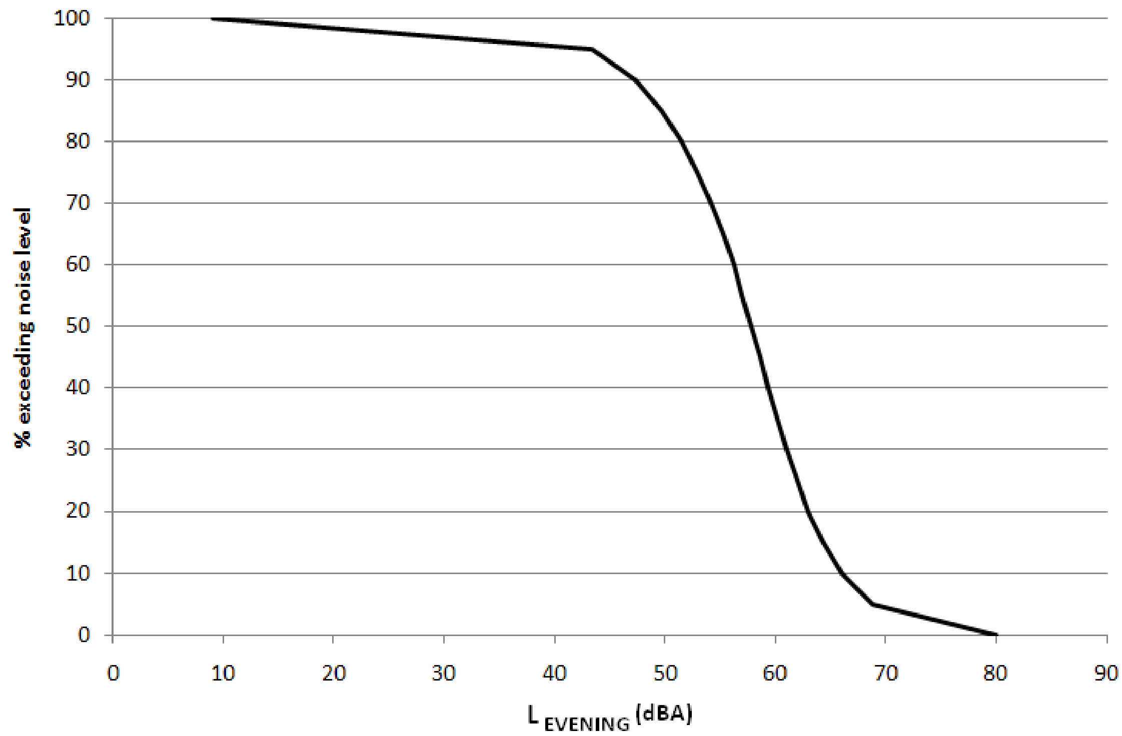

Figure 6.11: Cumulative frequency curve for $L_{EVENING}$ (Source: This Study)

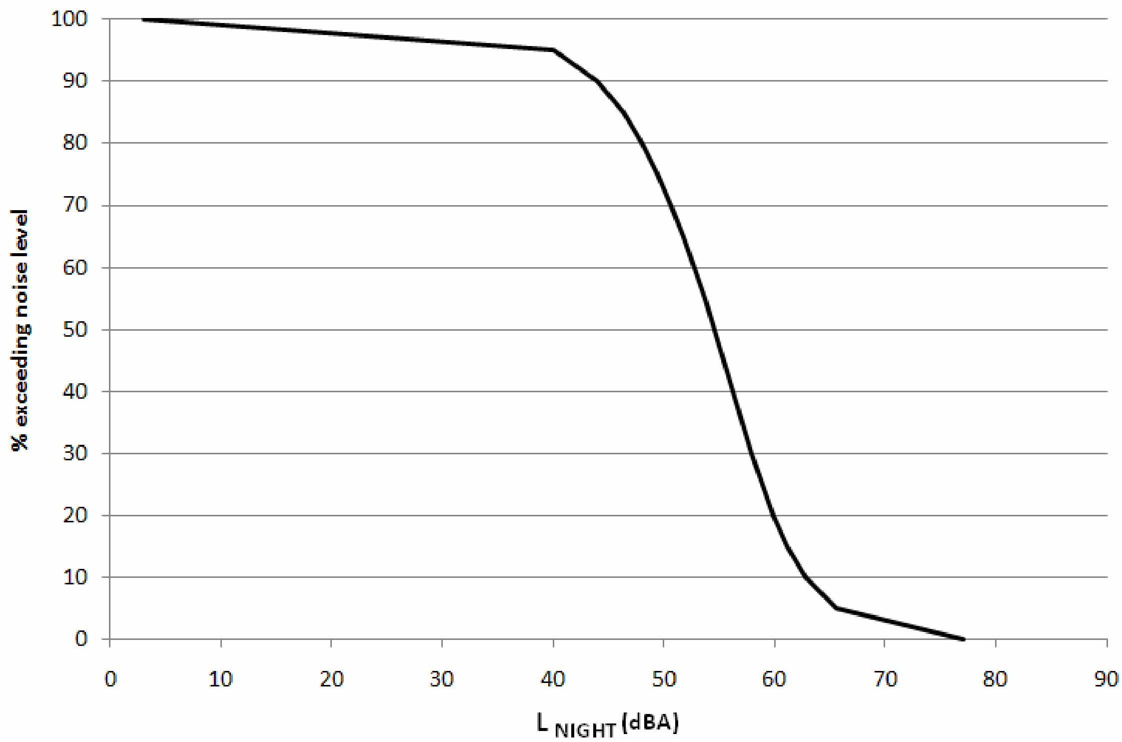

Figure 6.12: Cumulative frequency curve for L_{NIGHT} (Source: This Study)

6.2 Urban form, noise exposure and noise sources

This study has ascertained that urban form has significant effects on the acoustic environment in terms of noise exposure level and the noise sources. A total of seven common urban forms (old slab, cruciform, single/twin tower, trident, small houses, high-rise building with podium and high-rise building without podium) have been identified in Hong Kong. Only a small percentage (9.4%) of the sampled dwellings does not fall into any of the above urban form categories.

Figures 6.13 to 6.18 show the cumulative percentage of respondents exposed to different noise levels for various urban forms. In spite of their similarity, some observations could be made from these diagrams. Firstly, among these various urban forms, the small house category exhibits unique acoustic properties that are distinct from other forms. In comparison with others, it is exposed to the lowest level of traffic noise probably because small houses are located in areas where road traffic is minimal. Hence, residents are less annoyed by road traffic noise. However, the percentage of residents in small houses reporting annoyance due to outside animal is the highest among all urban forms. It should be noted that small houses are not common in Hong Kong and it would not be popular in spite of its acoustic friendly properties.

Secondly, the analysis results show that both transportation and non-transportation noises play a role in shaping the acoustic environment of various urban forms. As regards transportation noise, the two urban forms exposed to relatively high level of noise are high rise buildings with podium and high-rise buildings without podium. On the other hand, the two forms exposed to relatively lower levels of noise are cruciform and trident (Fig. 6.19). The lower noise exposure is due to the self-screening function of the building morphology. These two forms have also comparatively lower noise exposure levels at night (Fig. 6.19).

The third observation concerns non-transportation noise which differentiates different urban forms. The results show that single/ twin tower stands out from the others. This category has the highest percentage of respondents feeling highly annoyed by renovation and neighborhood noise. This could be explained by the light well design with which all dwellings are in light of sight with each other.

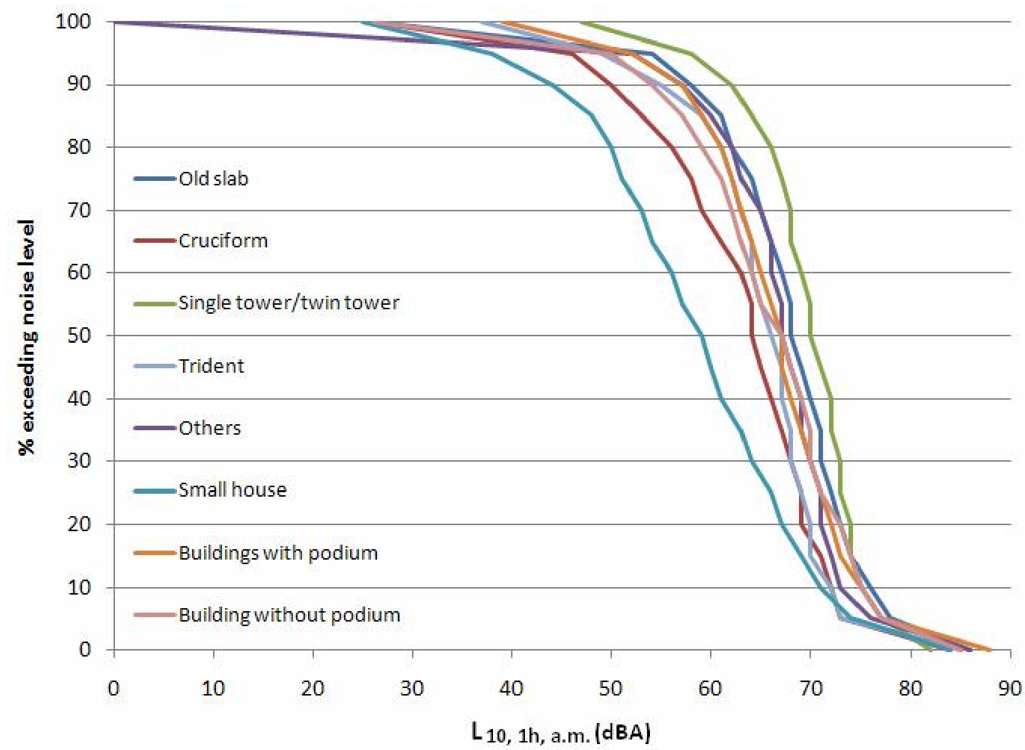

Figure 6.13: Cumulative frequency curves of various urban forms for L_{10AM} (Source: This Study)

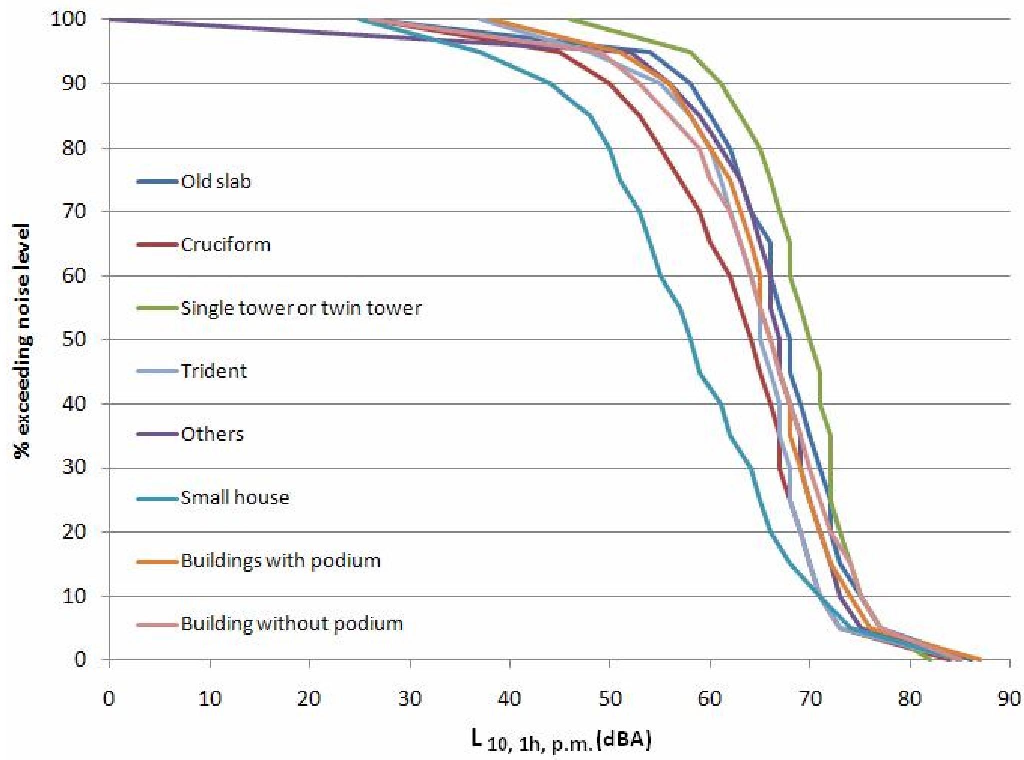

Figure 6.14: Cumulative frequency curves of various urban forms for L_{10PM} (Source: This Study)

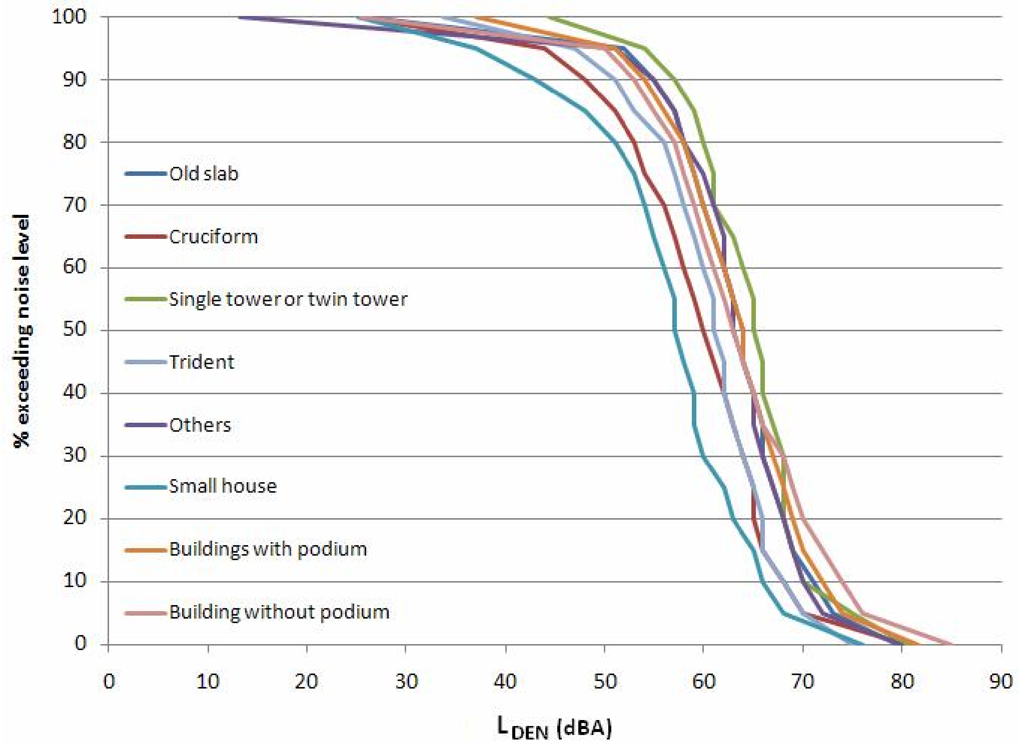

Figure 6.15: Cumulative frequency curves of various urban forms for L_{DEN} (Source: This Study)

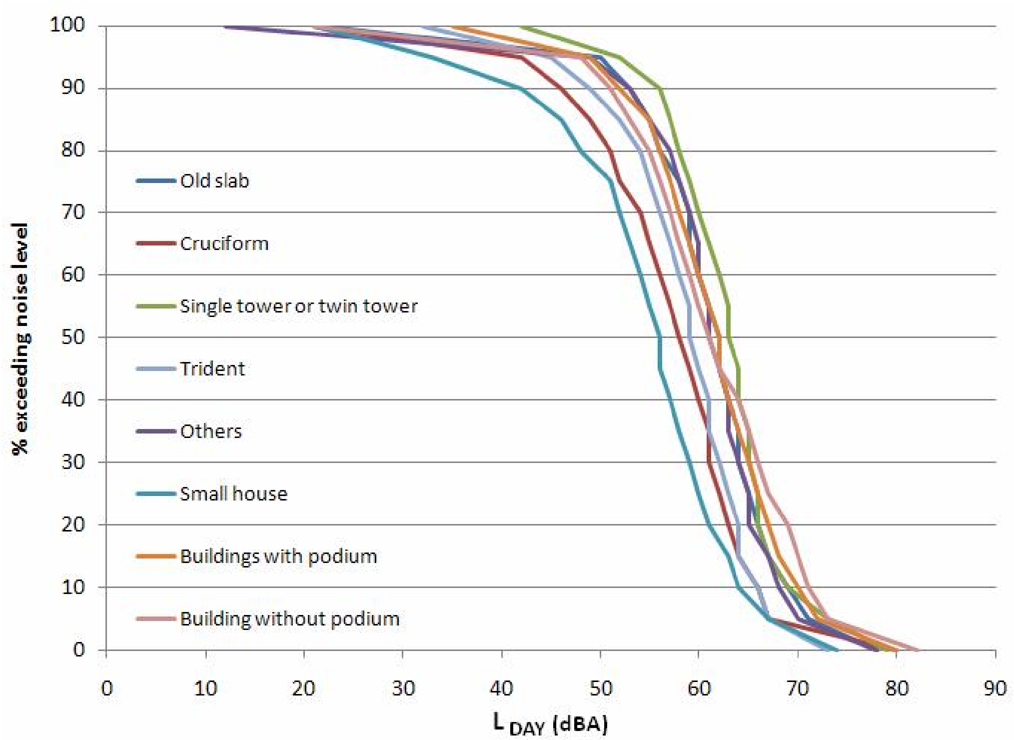

Figure 6.16: Cumulative frequency curves of various urban forms for L_{DAY} (Source: This Study)

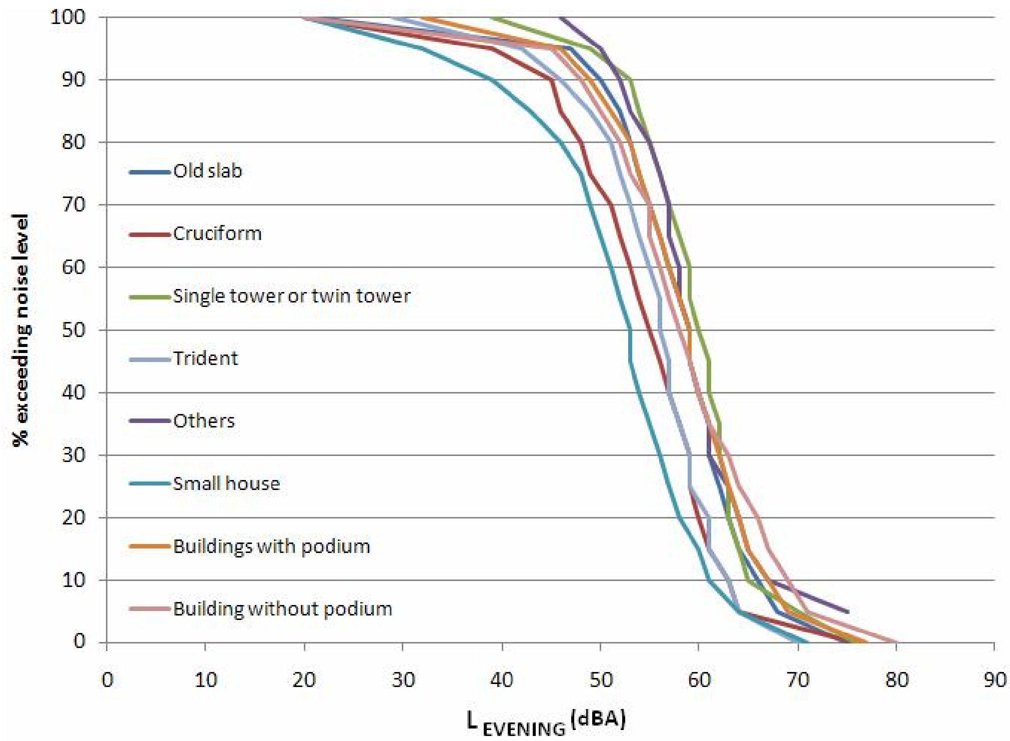

Figure 6.17: Cumulative frequency curves of various urban forms for $L_{EVENING}$ (Source: This Study)

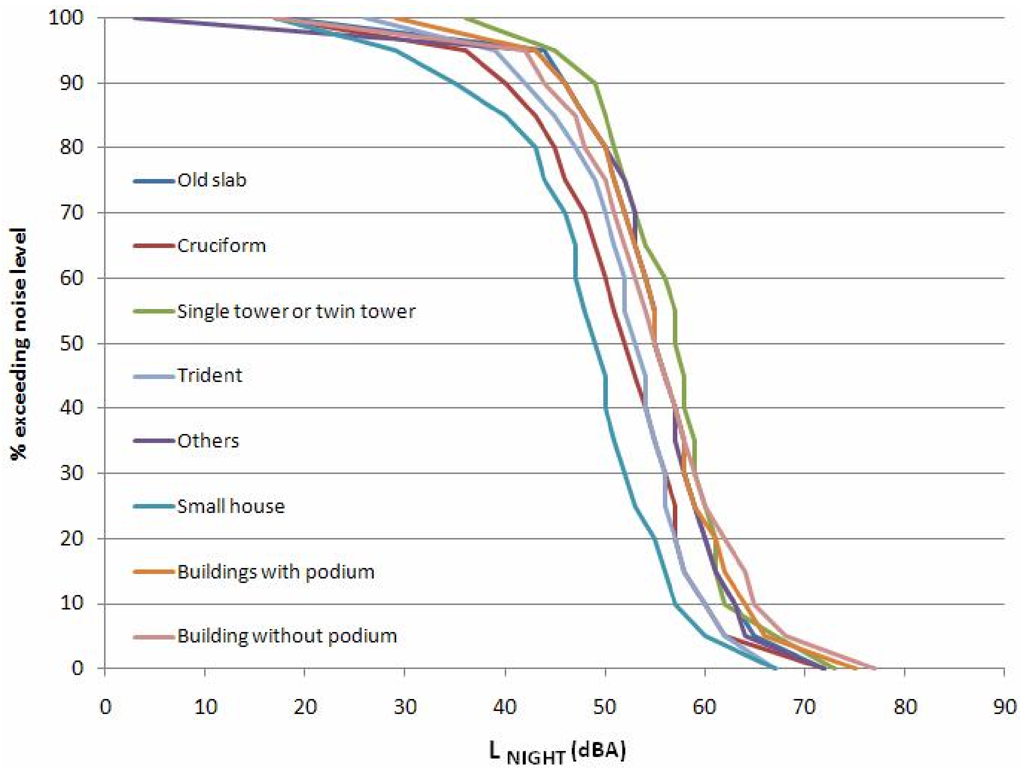

Figure 6.18: Cumulative frequency curves of various urban forms for L_{NIGHT} (Source: This Study)

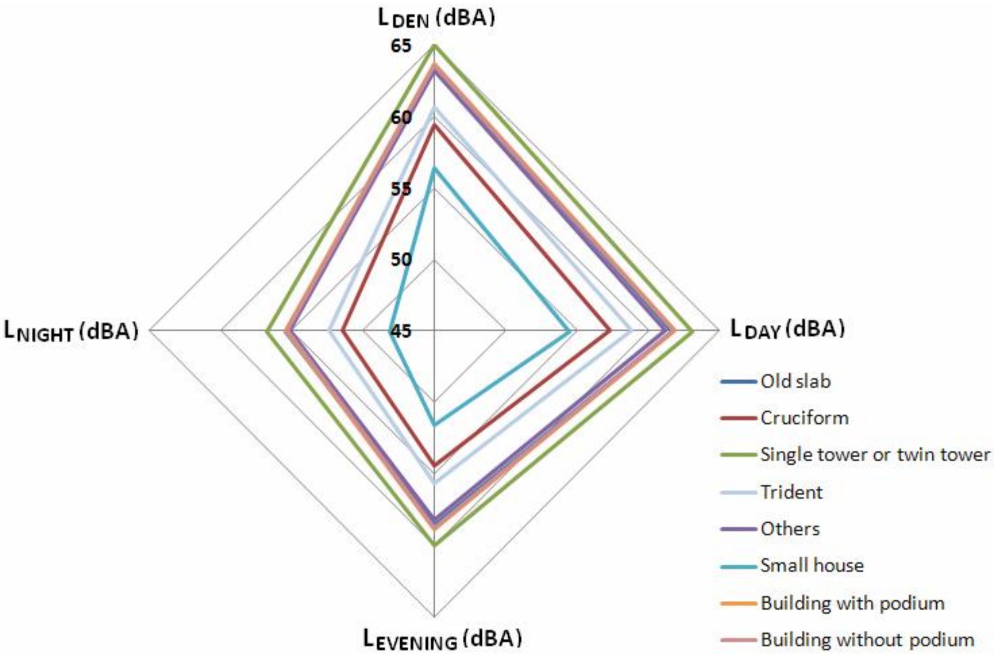

Figure 6.19: Mean of four noise metrics by urban form (Source: This Study)

The survey has also revealed significant variations in noise sources reported by respondents as annoying among different urban forms (Table 6.2). The highest percentages of respondents reporting road traffic noise as annoyance come from the categories of high-rise buildings *with* podium and high-rise buildings *without* podium. There are more people in small houses than in other urban forms reporting noise from outside animals as annoying. Likewise, more residents of the single/twin tower category report renovation and neighborhood noise.

Table 6.2: Percentage of respondent reporting noise sources that bother, disturb or annoy for different urban forms (Source: This Study)

	Percentage of respondents that regard a particular noise source to be bothering, disturbing, or annoying them (%)							
Noise Source	Old slab	Cruciform	Single tower or twin tower	Trident	Others	Small house	Building with podium	Building without podium
Road traffic	**24.75**	**32.34**	**28.57**	**30.40**	**29.58**	**17.48**	**38.75**	**34.59**
Aircraft	0.44	0.37	0.00	0.95	0.84	3.31	1.16	1.07
Marine	1.60	0.32	0.79	0.74	0.53	0.16	1.68	0.90
MTR, trains or LRT	0.73	1.85	0.79	1.59	2.11	0.47	2.76	1.52
Neighbours	**13.54**	**10.89**	**20.24**	**9.96**	**11.68**	**4.88**	**6.08**	**7.84**
Neighbour's air conditioning	0.29	1.67	2.38	1.59	1.26	0.00	1.34	1.47
Renovation	**14.26**	**11.45**	**23.81**	**17.27**	**14.42**	**2.68**	**14.45**	**11.46**
Residential building services	1.16	1.02	1.19	2.01	0.84	0.31	1.42	1.02
Alarm	0.44	0.79	1.19	1.80	0.74	0.00	0.67	0.62
Commercial activities	2.62	1.07	0.40	1.17	1.68	0.94	5.41	6.09
Industries/ factories/ machineries	0.15	0.42	0.00	0.42	0.53	0.31	1.87	1.52
Construction/ demolition	4.37	4.63	1.98	4.13	3.68	1.26	6.20	5.70
School	0.44	0.65	0.79	0.74	0.74	0.16	0.71	0.56
Animals outside	3.78	3.52	3.17	4.56	2.42	**19.37**	4.07	4.18
Playground/ sportsground	3.78	6.58	2.78	8.90	5.16	0.31	2.05	2.26
Noise in public areas	2.33	4.31	0.79	3.39	2.95	0.94	4.44	3.72
Wind Sound	0.00	0.00	0.00	0.00	0.00	0.16	0.04	0.00
No noise heard	47.02	43.37	39.29	38.98	46.21	**61.42**	37.44	43.74

Note: Respondents might name more than one noise source hence each column might add up to more than 100%

6.3 Response to road traffic noise

It can be seen from Figure 6.3 that 36.2% of the dwellings is exposed to road traffic noise in excess of L_{DEN} 65 dBA, a criterion commonly used in EU countries. This is the first time such estimate is derived for Hong Kong using a random representative sample.

Based on the questionnaire survey, the number of people among the adult population (aged 18 or above) who are highly annoyed throughout the day, highly annoyed at night and highly sleep disturbed are given in Table 6.3. The sampling design of the current study allows these precise estimates at the 95% confidence level. In lay terms, the number of people in Hong Kong aged 18 or above adversely affected by road traffic noise in the year 2010 are:

- Highly annoyed by road traffic noise throughout the day: 470,100 people
- Highly annoyed by road traffic noise at night: 294,600 people
- Highly sleep disturbed: 245,800 people

Table 6.3: Estimation of highly annoyed and highly sleep disturbed population aged 18 and above (Source: This Study)

	% of population	Confidence interval (%)*	Estimated number of population aged 18 or above (in thousands) in 2010
Highly annoyed	7.9	±0.526	438.6-504.0
Highly annoyed at night	4.95	±0.42	269.6-319.6
Highly sleep disturbed	4.13	±0.39	222.6-269.0

*Confidence level set at 0.95

It should be noted that the above estimates do not include 14.5% of the population who were below 18 in age and not covered in the study. Furthermore, these figures are reported by the respondents and cannot be verified by clinical conditions.

Considering that those who are highly annoyed throughout the day, at night or sleep disturbed may overlap, estimates have been made with regard to the number of people who may have one, two or all three adverse reactions. The tabulations show that a total of 856,100 people among the adult population of Hong Kong are annoyed by road traffic noise either throughout the whole day or at night; or are sleep disturbed. Among these people, 327,000 of them are adversely affected at night, reporting that they are either highly annoyed, or their sleep is highly disturbed, by road traffic noise. A small portion of them, amounting to 189,000, are both highly annoyed and highly sleep disturbed.

There are few studies which provide proportion of the population who are highly annoyed and/or who are highly sleep disturbed. The figures given in a report for the HYENA project (Babisch et al., 2009) are not directly comparable because the Hong Kong figure reported here is based on a random sample of the whole territory; whereas the figures for HYENA project are projected for areas adjoining the airports in certain cities. Despite the figures from HYENA are higher than that of Hong Kong, it cannot be said for sure that one is higher than the other because of the difference in sampling methodology.

It is also worthwhile to note that the various dimensions of human response (i.e. highly annoyed, highly annoyed at night and highly sleep disturbed) are all inter-related (Table 6.4). The correlation between "highly annoyed at night" and "highly sleep disturbed" is high.

Table 6.4: Correlation matrix of highly annoyed, highly annoyed at night and highly sleep disturbed (Source: This Study)

	How much you are bothered, disturbed, or **annoyed** by road traffic noises	How much noise from road traffic bother, disturb, or annoy you **at night**	How much is your **sleep** disturbed by road traffic noise
How much you are bothered, disturbed, or **annoyed** by road traffic noises			
How much noise from road traffic bother, disturb, or annoy you **at night**	0.571**		
How much is your **sleep** disturbed by road traffic noise	0.497**	0.724**	

**. Correlation is significant at the 0.01 level (2-tailed).

6.4 Exposure-effect relationship for road traffic noise in Hong Kong

To ascertain the response of the Hong Kong population to road traffic noise, it is customary to establish noise–effect curves. In this study, the term "effect" refers to (a) whether a person is "highly annoyed" (HA); and (b) whether a person is "highly sleep disturbed" (HSD) as per definition Miedema & Oudshoorn (2001) and Miedema et al. (2002) and described in section 2.4. The noise metrics used are L_{DEN} and L_{NIGHT} for HA and HSD respectively.

6.4.1. Exposure-effect curve based on L_{10}

Given that Hong Kong has used, for a few decades, $L_{10,\ 1h,}$ as the planning criterion, an attempt was made also to determine the exposure-effect relationship using this noise metric. Considering the only exposure-effect curve known to us based on $L_{10,\ 18}$ is from the U.K., the one produced by the UK Department of Transport (1994) is reproduced in this report for comparison. However, the methodology for producing the U.K. curve was given in the literature. It is not sure whether the top two most intense responses are from the top two on a 5-point scale. We have made the assumption that it is the case and prepared the curve for $L_{10,\ 1h}$ for Hong Kong based on the top two responses on the 5-point scale.

Another step involved in determining the exposure-effect curve is to look for the curve of best fit. In this study, 3 types of regression models (i.e. linear, 2nd order polynomial and 3rd order polynomial) were tried for each data set and the one which fits best, based on R^2, was selected.

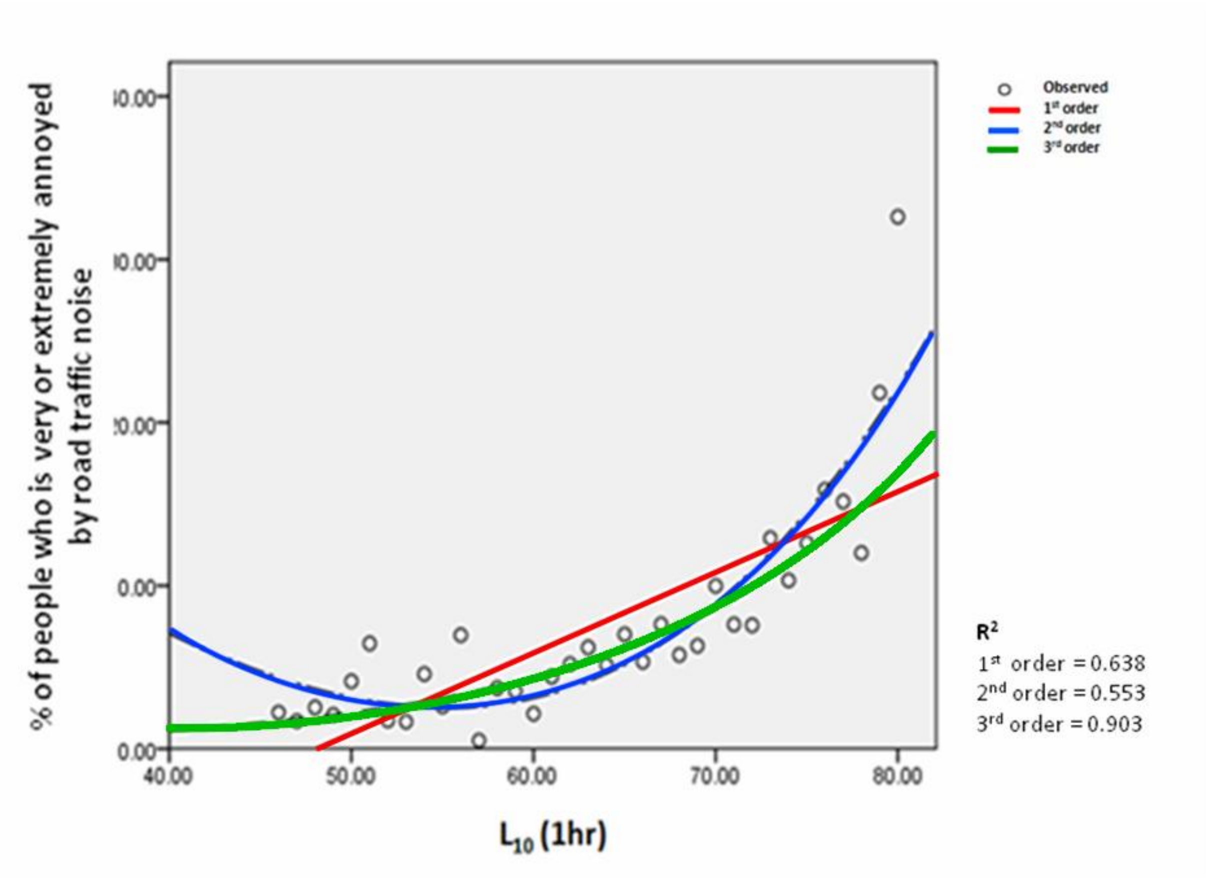

Figure 6.20: Curve fitting for Hong Kong's L_{10} exposure-effect curves (Source: This Study)

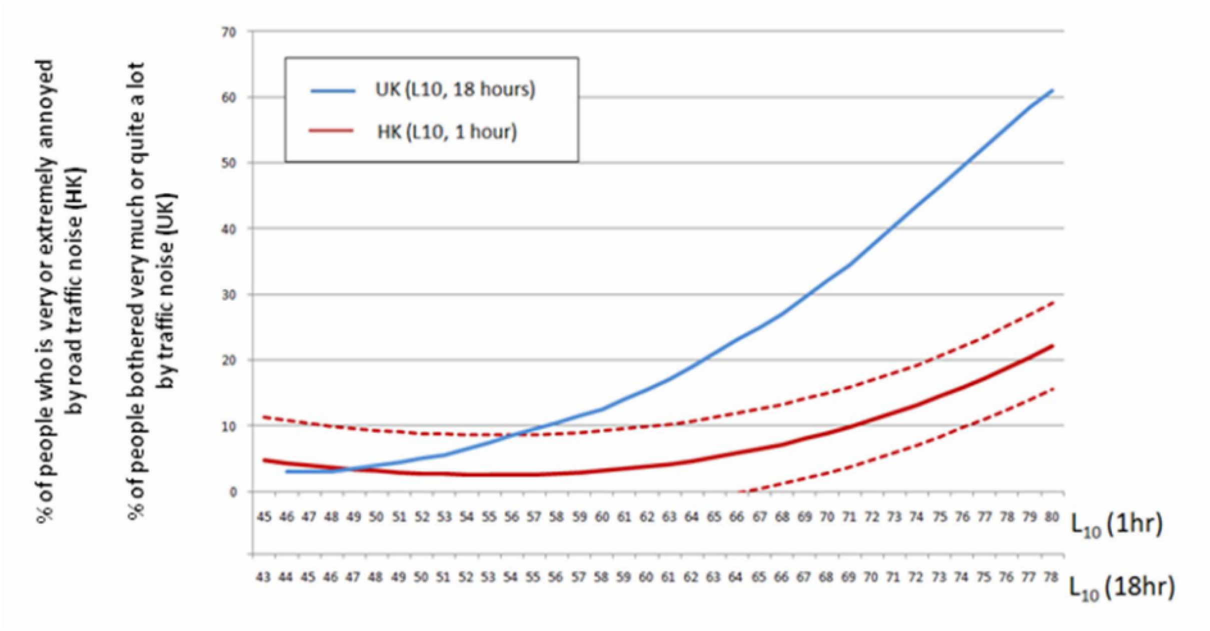

Figure 6.21: Comparison of Hong Kong and UK L_{10} exposure-effect curves (Source: This Study)
(*R^2 for Hong Kong's curve = 0.812)

It was determined that the 3rd order polynomial (Figure 6.20) provides the best fit, and the curve (Figure 6.21) is presented together with the curve previously obtained in the U.K. At the first glance, the Hong Kong curve appears to be lower than the UK curve, but one must be extremely cautious that the comparison cannot be made for two reasons. Firstly, it is not known exactly how the question was framed and posed in the UK study. Secondly, it is not known what the population was in the UK study (i.e. whether it was based on same sample design as in Hong Kong; or whether the UK study targeted only those exposed to noise from major roads).

6.4.2. Exposure-effect curve based on L_{DEN}

Following the WHO practice, the following analysis was based on L_{eq} noise metrics, such as L_{DEN}, L_{DAY}, $L_{EVENING}$, and L_{NIGHT}. Such metrics are being adopted in an increasing number of countries and promoted as standard in the EU. Of the above four metrics, L_{DEN} and L_{NIGHT} are directly related to the foci of the current study, namely % HA and %HSD respectively. In the analysis, we derived the percentage of respondents who are highly annoyed, or highly sleep disturbed, for each band of 1 dB. The %HA was then plotted against the noise exposure level, and the curve of best fit was obtained by trying out three curves.

Figures 6.22 and 6.23 show the lines of best fit for Highly Annoyed and Highly Sleep Disturbed respectively. We adopted a lower cut off point of 45 dB because it is known that noise exposure estimates by noise mapping are not accurate in the low exposure range for the lack of reliable traffic flow data. All noise exposure data at the higher end are included. Based on the R^2, we have determined that the lines of best fit are 3rd order polynomial for both HA and HSD.

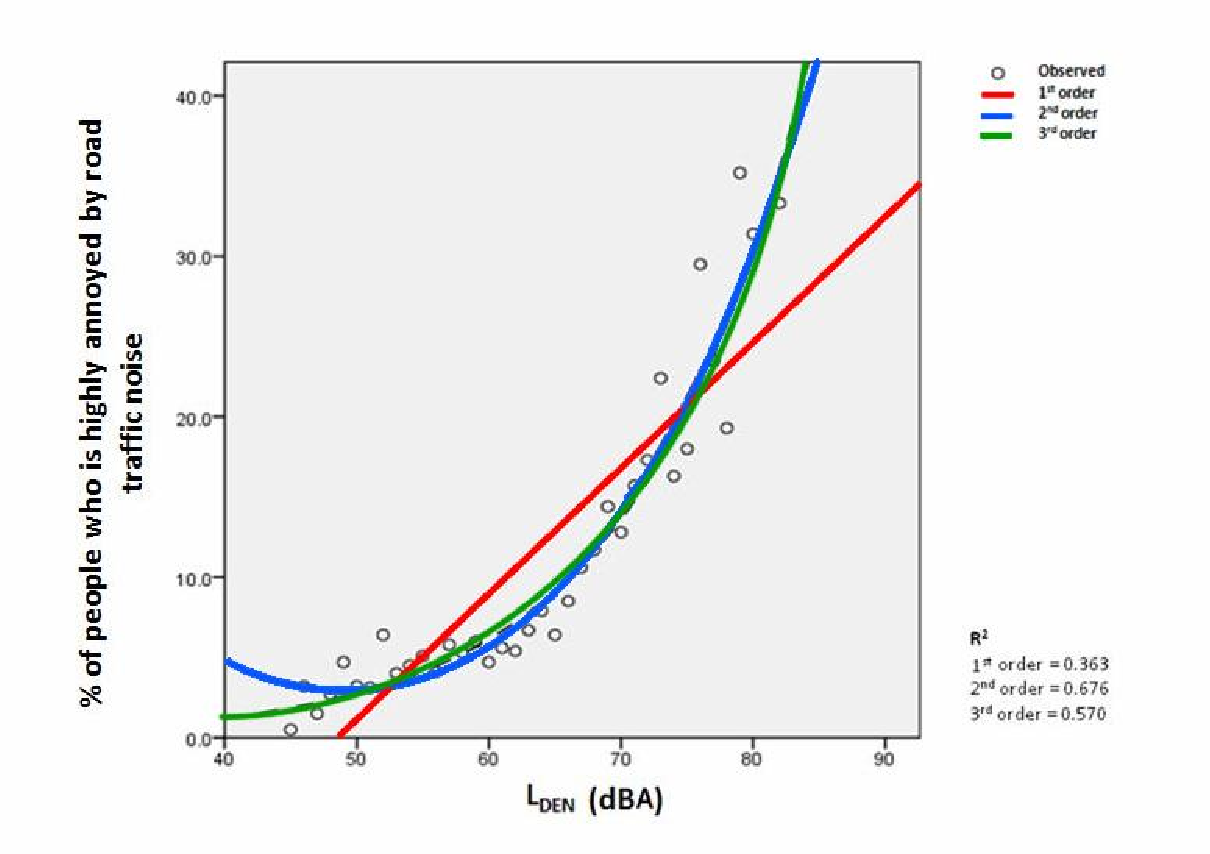

Figure 6.22: Curve fitting for L_{DEN} exposure-effect curves (Source: This Study)

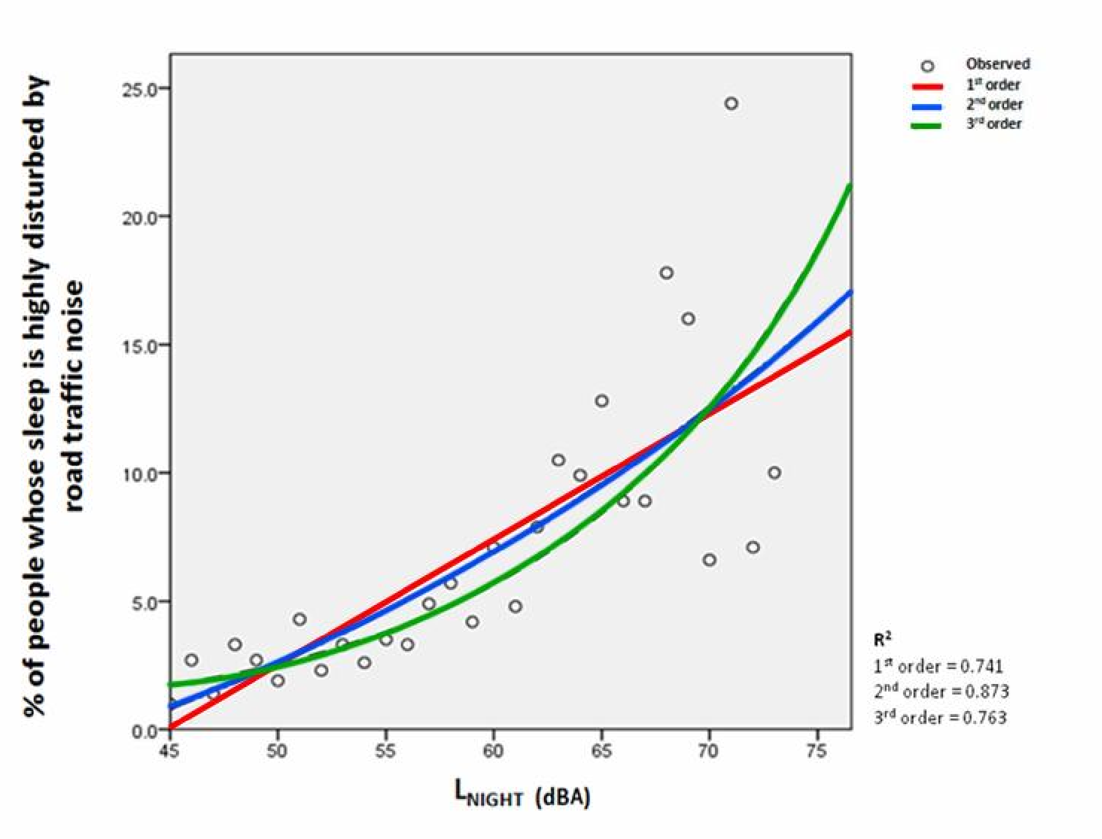

Figure 6.23: Curve fitting for L_{NIGHT} exposure-effect curves (Source: This Study)

6.3 Comparison with other studies

One of the objectives of the study is to compare the response of the Hong Kong population to transportation noise with that of previous studies. We are keenly aware that any comparison must be done on a like-for-like basis and has to proceed with extreme caution. Such comparison will not be meaningful should any of following occur: (a) the questions posed to the respondents are not the same; (b) different scales of response are used; (c) the target populations are different; and (d) the methods of sampling are different. Considering that the ISO document on the design of questionnaire for social survey (ISO/TS 15666, 2003) was only promulgated in 2003, the number of studies meeting the above criteria for comparison is indeed very limited.

Notwithstanding, we have identified that the following curves are apt for comparison:

- Midema & Oudshoorn (2001)
- Phan et al. (2008)

It should, however, be noted that the Miedema curve is the synthesis of quite a number of individual curves. Hence, the Miedema curve is more appropriately seen as a zone (well defined confidence interval) rather than a single curve. This fact must be recognized if any comparison is to be made. The curves produced by Phan et al. (2008) are particularly relevant because the study was undertaken in Vietnam, a country in Asia with a similar cultural background.

Following Miedema's suggestion, cases with noise exposure <45 dBA and >75 dBA were disregarded and the curve, based on %HA, so derived is given in Figure 6.24 which also portrays those produced by Miedema & Oudshoorn (2001) and Phan et al. (2008). The confidence intervals are given wherever such data is available. The Miedema curve for railway noise is also given as a reference. In plotting these curves, we have limited the noise exposure to 45 to 75 dB L_{DEN}, following Miedema's suggestion. Furthermore, we have included all "0" (not at all) on the 0 to 10 response range. By giving a response of "0", it is not known if the respondent is exposed to road traffic noise.

A few observations can be made from Figure 6.24. Firstly, The Hong Kong curve appears to be below that of Miedema's road traffic curve, but is close to Miedema's railway noise curve. Secondly, the Hong Kong curve appears to lie in the same region of the Phan's curves for two Vietnamese cities. Thirdly, it appears that in the high exposure range, Hong Kong curve is below Miedema's but close to that of Vietnamese cities which are also Asian cities.

The same analysis has been applied to the highly sleep disturbed (%HSD) data (Figure 6.25). It can be seen that the Hong Kong curve lies below the Miediema's curve for road traffic, and it is close to Miedema's curve for railway.

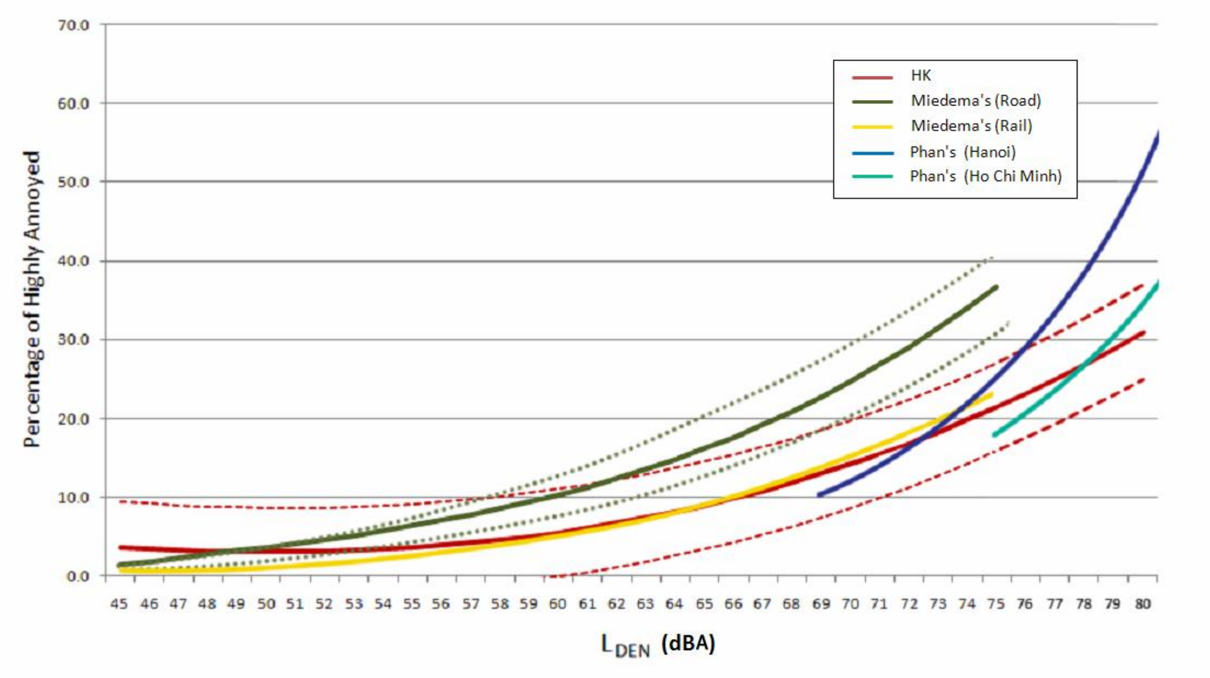

Figure 6.24: Comparison of L_{DEN} exposure-effect curves (Source: This Study)

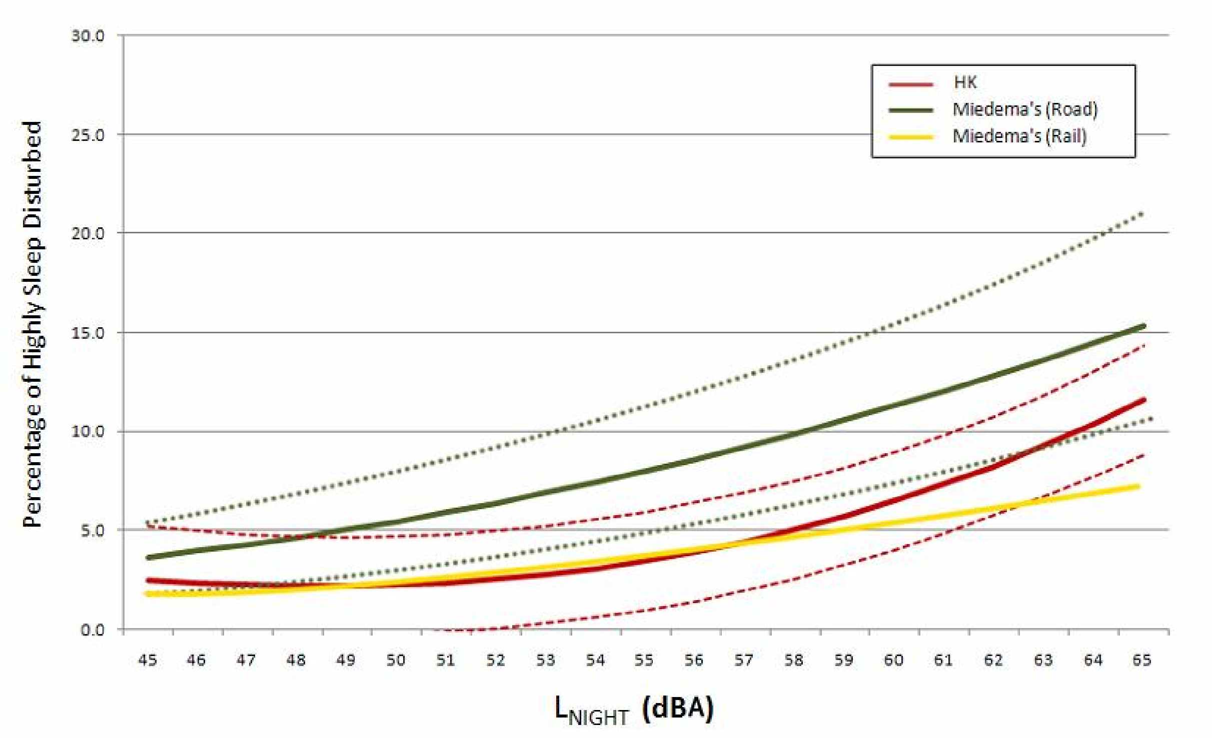

Figure 6.25: Comparison of L_{NIGHT} exposure-effect curves (Source: This Study)

6.4 Factors affecting annoyance and sleep disturbance effects in Hong Kong

To elucidate demographic, personal and social factors which affect annoyance and sleep disturbance in Hong Kong, the binary logistic regression analysis was undertaken both for annoyance and sleep disturbance. The dependent variable is the percentage of respondents highly annoyed or highly sleep disturbed. Independent variables were taken from those derived from the survey. They can be grouped into 4 blocks (Table 6.5). The first, of course, is the noise exposure level, expressed in terms of L_{DEN} and L_{NIGHT}. The second group of variables is those which may affect the noise exposure at home, namely, access to quiet room, closing window, crowdedness, number of households in the living quarters. We believed variables in this block may be relevant because they may modify the noise exposure particularly inside the dwelling. The third are factors which may affect one's perception of the environment, namely, satisfaction with neighborhood environment, ownership, living quarter type and length of residence. We believe that ownership and housing quarter type may affect expectation and length of residence may help ascertain if habituation to noise exists. The last block includes all other personal factors, namely noise sensitivity, disease, health status, hearing problems, poverty, gender, age, employment, shift-worker, education level, occupation, monthly household income, sleep outside curfew and sleep deprivation. Some studies have shown that noise sensitivity is a significant factor affecting annoyance and socio-economic factors do affect the level of annoyance.

Table 6.5: List of independent variables for regression model (Source: This Study)

Block 1			
Noise exposure	**ABBREVIATION**	**DESCRIPTION**	**CODING**
	L_{DEN} for 24h	Noise exposure to road traffic for annoyance response	
	L_{NIGHT}	Noise exposure to road traffic for sleep disturbance response	
Block 2			
Physical factors affecting noise exposure	QUIETROOM	Household have one or bedrooms NOT directly facing road or railways	0 = no; 1 = yes
	WIN_CLSE	Closing windows during the day when there are people at home (for L_{DEN} for 24h); closing windows during the sleep (for L_{NIGHT})	0 = no; 1 = yes
	CROWD	Crowdedness: total of rooms including all, but except kitchen and bathroom/ total number of household members	1 = 0.5 or less rooms/person; 2 = 0.51-1.99 rooms/person; 3 = 2 or more rooms/person
	NO_HSEHLD	Number of household in a dwelling	
Block 3			
Personal factors affecting perception	RESAT	Satisfaction living in the estate/ street block	1 = highly dissatisfied plus dissatisfied; 2 = neither satisfied or dissatisfied; 3 = satisfied plus highly satisfied
	OWNER	Household rent or own this house/ flat	0 = non-owner; 1 = owner
	HTYPE	Type of living quarters	0 = public; 1 = private
	RESIDENCE	Length of residence	Years
Block 4			
Other personal factors	NOISESEN	A noise sensitivity score is created, ranging between 0 and 35. To convert the noise sensitivity score into 3 tertile groups (low, medium, high), scores between 0 and 16 accounting for about 33% of the respondents is recoded as 1. Scores between 17 and 20 accounting for another 33% is recoded as 2. The rest, scoring between 21 and 35, is recoded as 3.	1 = low; 2 = medium; 3 = high
	GHS	General health status (This variable uses the guidelines of SF36. The response is calculated as: (raw score minus minimum score) / score range * 100.) The transformation becomes from a 1-5 scale to a 0-100 scale.	The response of this variable is from 1 (very poor) to 5 (very good), so the minimum score is 1 and the score range is 4.
	HEARDIFF	Have hearing problems or difficulty	0 = no; 1 = yes
	POVERTY	Poverty (Our definition here is close to HKCSS 2010 Report's – family with monthly household income lower than the following amount is considered to be in poverty: 1 household member $3275; 2	0 = no; 1 = yes

		household members $7100; 3 household members $11000; 4 or more household members $12000)	
	GENDER_MALE	Gender	0 = female; 1 = male
	AGE	Age	Years
	EMPLOY	Employment status	1 = not employed; 2 = part-time; 3 = full-time
	SHFTWORK	Overnight shift work	1 = non overnight shift worker (other than 2 and 3, all including not employed, becomes 1); 2 = frequently work overnight shift; 3 = alternative day & night shift
	ELEVEL	Education level attained	1 = primary; 2 = secondary; 3 = tertiary
	OCCUPATN	Occupation	
	HSEINCOME	Average monthly household income	1 = lower quartile; 2 = median; 3 = upper quartile
	SLPOUTSIDECURF	Sleep outside curfew (Coded as 1 if the respondent sleeps between 0700h and 2300h; if not, coded as 0.)	0 = no; 1 = yes
	SLPDEPRIVED	Sleep deprived (Defined as the respondent's actual sleep duration is less than the duration he/ she desires.)	0 = no; 1 = yes

Table 6.6: Results of the Principal Component Analysis for variables used in the binary logistic regression analysis for highly annoyance (Source: This Study)

Highly annoyed	Component				
	1	2	3	4	5
L_{NIGHT}	.009	.126	**.575**	.099	.277
QUIETROOM	-.086	-.071	-.383	.093	-.195
WIN_CLSE_DAY	.093	.070	.088	.226	-.273
CROWD	.150	**.641**	-.055	-.036	-.091
NO_HSEHLD	.031	-.079	**.509**	**.418**	.012
RESAT	.050	.082	-.351	.013	-.160
OWNER	.257	**.697**	-.194	-.139	-.021
HTYPE	.352	**.674**	.256	.150	-.067
RESIDENCE	.135	-.018	.390	.217	-.164
NOISESEN	.078	-.073	.254	**-.400**	.158
DISEASE	-.499	.250	.040	-.158	**.374**
GHS	.377	-.146	-.079	.188	-.275
HEARDIFF	-.283	.174	-.040	-.064	**.341**
POVERTY	-.583	-.118	.123	-.054	-.181
GENDER_MALE	.160	-.060	-.220	.269	**.364**
AGE	**-.719**	.307	-.112	.062	.201
EMPLOY	**.778**	-.153	-.119	.114	**.308**
SHFTWORK	.177	-.125	-.091	.090	**.376**
ELEVEL	**.710**	.125	.012	-.030	-.097
OCCUPATN	**.802**	.022	-.097	.050	.222
HSEINCOME	-.102	.119	.117	-.206	**-.353**
SLPOUTSIDECURF	-.431	.101	-.150	**.499**	.073
SLPDEPRIVED	.287	-.136	.146	**-.571**	.048

Table 6.7: Results of the Principal Component Analysis for variables used in the binary logistic regression analysis for highly sleep disturbance (Source: This Study)

Highly sleep disturbed	Component				
	1	2	3	4	5
L_{NIGHT}	.002	.107	**.557**	.196	.228
WIN_CLSE_SLEEP	.115	.130	.161	.039	-.171
QUIETROOM	-.087	-.070	-.384	.033	-.227
CROWD	.151	**.641**	-.051	-.054	-.074
NO_HSEHLD	.030	-.081	**.491**	**.420**	-.080
RESAT	.050	.079	-.354	-.022	-.196
OWNER	.259	**.695**	-.193	-.138	.013
HTYPE	.354	**.673**	.249	.143	-.099
RESIDENCE	.135	-.018	.386	.189	-.223
NOISESEN	.080	-.069	.269	-.316	.197
DISEASE	-.498	.249	.035	-.058	**.408**
GHS	.377	-.147	-.079	.141	**-.382**
HEARDIFF	-.283	.171	-.052	.029	**.340**
POVERTY	-.584	-.116	.128	-.090	-.166
GENDER_MALE	.160	-.063	-.233	.347	.282
AGE	**-.718**	.307	-.117	.108	.179
EMPLOY	**.777**	-.157	-.128	.184	.269
SHFTWORK	.177	-.126	-.096	.179	**.333**
ELEVEL	**.710**	.123	.010	-.049	-.086
OCCUPATN	**.802**	.017	-.105	.104	.201
HSEINCOME	-.102	.121	.125	-.272	**-.307**
SLPOUTSIDECURF	-.432	.100	-.157	**.503**	-.076
SLPDEPRIVED	.288	-.136	.153	**-.553**	.232

Considering that the afore-mentioned variables are closely inter-related, principle component analyses were undertaken for variables used to predict percentage of highly annoyed (Table 6.6) and percentage of highly sleep disturbed (Table 6.7), it can be seen that there is close association among age, education level and employment status; housing type, ownership and crowdedness; noise sensitivity, sleep deprivation and sleeping outside curfew hours.

All these variables were entered block by block, leaving the regression to pick automatically variables meeting the 0.05 significance criterion. The results are expressed in terms of "odds ratio". An odds ratio > 1 indicates that particular variable intensifies the annoyance reaction. Conversely, a ratio < 1 signifies the variable reduces or moderates annoyance reaction. The results in Tables 6.8 and 6.9 show also the change in Nagelkerke coefficient indicating the additional explanatory of selected variables of a particular block.

Regarding the "highly annoyed" response, the regression analysis has identified a total of 10 variables (Table 6.8). Among these factors, noise exposure level is found to have a very small effect (odds ratio = 1.078) on invoking annoyance reaction. The results also show that factors which **intensify** the annoyance response include, in order of importance, noise sensitivity, window closing and whether the respondent is the owner of the dwelling. On the other hand, factors which can **reduce** annoyance reaction include: access to a quiet room in the dwelling, satisfaction with the environment in the neighborhood and the number of households in the living quarters. It can be seen that window closing has a positive association with annoyance. This association does not tell whether window closing is the outcome of noise exposure or a casual factor of annoyance. The study also ascertained that the annoyance reaction can be reduced if the respondent can access a quiet room in the dwelling or is satisfied with the neighborhood environment. These findings are in line with previous studies (Persson Waye et al., 2003; Bluhm et al., 2004; Babisch et al., 2005; Gidlof-Gunnarsson et al., 2007; Botteldooren et al., 2011).

To sum up, this study has highlighted three findings of significance. Firstly, it has affirmed that access to a quiet room and satisfaction with the neighborhood are positive factors that may moderate or reduce annoyance. Secondly, the study affirms that there is no evidence of habituation. In other words, the length of residence does not help moderate annoyance reaction. Finally, no demographic or socio-economic variable has been found to be significant in either intensifying or moderating the annoyance reaction. The last findings are also consistent with the findings of earlier studies undertaken by Lam in Hong Kong (Lam & Marafa, 2011).

The regression analysis results for "highly sleep disturbed" reactions (Table 6.9) are similar to those for "highly annoyed" response (Table 6.2) in several ways. Firstly, noise exposure level, L_{NIGHT}, has an only a small effect. Secondly, noise sensitivity, disease and window closing are the three most important factors affecting sleep disturbance response. Like "highly annoyance" reaction, access to a quiet room and satisfaction with the neighborhood can moderate annoyance reaction.

In both analyses, the respondent's education, income and employment are not related to annoyance and sleep disturbance reactions.

Table 6.8: Logistic regression of factors affecting annoyance (Source: This Study)

Description	Beta coefficient	Level of significance	Odds ratio	Cumulative Nagelkerke R Square	Change in Nagelkerke R Square
Noise exposure					
Noise exposure (L_{DEN})	.074	.000	1.077	.058	/
Physical factors affecting noise exposure					
Access to quiet room	-.758	.000	.469	.088	.03
Closing window	.257	.000	1.293		
Number of household	-.275	.005	.760		
Personal factors affecting perception					
Satisfaction with neighborhood environment	-.602	.000	.548	.119	.031
Ownership	.218	.008	1.244		
Other personal factors					
Interviewee's noise sensitivity	.453	.000	1.573	.140	.021
Hearing problems	.481	.012	1.618		
Education Level	.132	.032	1.141		

Table 6.9: Logistic regression of factors affecting sleep disturbance (Source: This Study)

Description	Beta coefficient	Level of significance	Odds ratio	Cumulative Nagelkerke R Square	Change in Nagelkerke R Square
Noise exposure					
Noise exposure (L_{NIGHT})	.086	.000	1.089	.057	/
Physical factors affecting noise exposure					
Access to quiet room	-.821	.000	.440	.083	.026
Number of household	-.350	.014	.704		
Personal factors affecting perception					
Satisfaction with neighborhood environment	-.460	.000	.631	.099	.016
Other personal factors					
Interviewee's noise sensitivity	.715	.000	2.044	.139	.04
Education level	.201	.012	1.222		

6.5 Discussions of findings

This study was undertaken to determine the extent to which the Hong Kong population is annoyed, and their sleep disturbed, by road traffic noise. At the outset, the study team was aware of the pros and cons of different sampling strategies and the need to strike a balance between what is desirable and what is practically feasible. Taking advantage of the "Thematic Household Survey" done by the Census and Survey Department, the study adopted an equal probability sampling design, covering the whole of Hong Kong, embracing the urban and rural areas, the city as well as the countryside. This sampling design is akin to random sampling. While such an approach can give very reliable estimates of the number of people in Hong Kong highly annoyed and highly sleep disturbed by road traffic noise, the approach does not give adequate information of those who are exposed to rail and aircraft noise which affects a small proportion of the population at specific locations. Furthermore, it does not cover the high, medium and low exposure groups uniformly. Because of these constraints, noise exposure data are available only for road traffic and the current study can focuses only on the effects of road traffic noise on the Hong Kong population.

While attempts have been made to compare the findings of Hong Kong with those undertaken elsewhere, such comparisons must take into account the differences in the sampling strategy and the methodology. For example, this study surveys the whole of Hong Kong and most previous studies targeted the city or only part of the city. Some even focused on areas adjacent to major motorways, airports or particular regions of the city exposed to noise of a particular noise such as aircraft or rail.

There is another reason why findings of this study are not directly comparable to most previous studies. As elaborated in section 5.1 of this report, there had been hundreds of studies investigating annoyance and sleep disturbance caused by transportation noise. They used different sampling strategies, response scales, questions and wording. It was not until the turn of the century that the scientific community recognized the difficulties in comparing oranges with apples and highlighted the need to standardize question setting and methodology (Fields et al., 2003). The promulgation of the ISO standard on questionnaire design (ISO/TS 15666, 2003) has helped a lot and this is one of the few large scale city-wide studies strictly following the ISO approach. It follows that, strictly speaking, results of this study are not directly comparable to the majority of previous studies which used different questions, response scales, target population and way of defining "highly annoyed" and "highly sleep disturbed". Probably, the best available (but somewhat outdated) one that can be compared with is the exposure-effect curves prepared by Miedema & Oudshoorn (2001). However, that particular curve was not derived from a city or country, but synthesized from a number of other studies. In fact, the Miedema curve is not just a line, but a zone where most of the curves lie.

This study has ascertained that 36.2% of the Hong Kong population are exposed to $L_{DEN} > 65$ dBA on the most exposed side of their dwellings. It is also estimated that 7.9% and 4.13% of the population are highly annoyed and highly sleep disturbed respectively. These are sizeable numbers considering the potential health effects of transportation noise.

For the first time, this study has produced exposure-effect curves for the whole of Hong Kong. This is also the first city-wide study in the Asian region. While the Hong Kong curve is below the Miedema curve suggesting that the Hong Kong population is less annoyed than others at the same exposure level, any comparison must be couched in cautious terms. A number of observations merit special mentioning. Firstly, the Hong Kong curve lies close to Miedema's curve for railway noise. Secondly, the Hong Kong curve is in the same region as the curves derived by Phan et al. (2008) for Hanoi and Ho Chi Minh City.

If the Hong Kong curve is indeed different from Miedema's, the question that follows is obviously why. It must be recognized that the current study was not designed to collect all the information needed to provide the answer. We have collected data to determine *if* differences exist, but not *why* they exist. Some plausible reasons can be offered but they are at best hypothetical. A specifically design study has to be undertaken to probe into the causes of discrepancy.

The first plausible explanation of the less strong annoyance reaction is due to a culture that values big families and does not mind crowdedness. A number of studies (Chan, 1999; Lee, 1985) on the social effects of high density living suggest that Hong Kong people are more tolerant to density than others. Whether or not there is parallel between noise and density tolerance has yet to be ascertained. It should however be noted that "the length of residence" has not been found to be a significant factor moderating noise induced annoyance or sleep disturbance, as no evidence of habituation in other studies (Weinstein, 1978).

Another plausible reason can be found in the indoor outdoor difference in noise levels. Most of the noise exposure effect studies are based on estimates of outdoor noise level, typically at the façade of the building most exposed to traffic noise. However, human response is shaped more by the noise level inside rather than outside the dwelling. It is likely that the indoor-outdoor difference in noise exposure is greater in Hong Kong than in other regions. This can be ascribed to the sub-tropical climate in Hong Kong and the fact that more than 90%, and more than 70%, of the respondents turning on their air-conditioners (Table 4.12) or closing the window respectively (Tables 4.13 and 4.14) for most of the time in the year. Under such circumstances, outside noise levels may have little relationship with the noise exposure inside the dwelling. Having that said, it does not follow that there is sufficient ground to relax the existing noise planning standard. A compelling reason of not doing so is based on ground of environmental equity. The installation of air conditioning units is income-biased. It is not a measure that can be afforded by the more deprived class of the society. Any move to relax the noise standard will have a disproportionate effect on the low-income groups of the society.

Chapter Seven: Conclusions and recommendations

Commissioned by the Hong Kong Environmental Protection Department and undertaken by The Chinese University of Hong Kong, this study looks into the health effects of transportation noise. Among the various effects of noise, the study focused on annoyance, sleep disturbance and cardiovascular disease. This is the first systematic city-wide study in Hong Kong and one of the few in the world closely following the ISO/TS 15666 protocol on survey methodology. It attempts to identify the key health effects of transportation noise by reviewing the recent scientific literature and undertaking a large scale survey of the Hong Kong population using a carefully thought out sampling and interview techniques.

This study was supported by a separate noise mapping exercise assessing the noise exposure levels of the whole city and a social survey implemented by the Census and Survey Department as part of their "thematic survey" studies. A total of 10,077 households were successfully interviewed and noise exposure level from road traffic assessed. The study team designed the questionnaire and trained the interviewers of the social survey.

In undertaking the study, the study team was keenly aware of the need to design a questionnaire that will provide the data required to address the study objectives and for possible comparison with previous similar studies. The ISO/TS 15666 recommended standards in setting survey questions were strictly adhered to; and a meticulous protocol had been developed to ensure that all questions were professionally posed; carefully framed and diligently executed. A quality assurance scheme was in place to ascertain validity and assurance accuracy.

As part of the Government's "thematic survey" program, a representative quasi-random sample was selected to cover the whole of Hong Kong. While such a strategy will provide reliable and accurate estimates of people adversely affected by transportation noise, it did not give adequate coverage on all transportation noise sources (e.g. aircraft and rail). This is nonetheless a useful attempt given time and resource constraints and the current study must be seen as the first systematic survey of noise effects for the whole of Hong Kong. Given these constraints, the current study only focused on road traffic noise – its prevalence and its effects on the Hong Kong population. It is suggested future studies can be extended to rail and aircraft noise but a disproportionate stratified sampling approach has to be considered.

In addition to the noise exposure and human response data, the study has also collected a large array of related data on noise sensitivity, sleep pattern, noise coping behavior and self reported noise sources. They are useful information not only to explain the findings of this study, but also to provide insight on living habits of the population in a dense compact city.

The large sample size enabled the team to determine that 28.9% and 36.2% of the sampled dwellings are exposed to maximum road traffic noise in excess of $L_{10,1h}$ 70 dBA and L_{DEN} 65 dBA respectively at the most exposed dwelling facade. The latter is the first ever estimate made before in Hong Kong. The study has also ascertained that the pursuit of good acoustic environment ranks 4^{th} in the evaluation of the urban environment and about 30% of the Hong

Kong population reported sleep problems. The latter group of people is particularly vulnerable to noise pollution particularly at night.

Thanks to the rigorous sampling and questionnaire methodology, the study could reliably estimate that 470,100 people and 294,600 people among the adult population (aged 18 or above) are highly annoyed and highly sleep disturbed respectively by road traffic noise in 2010. 327,000 of these people reported that they are either highly annoyed, or highly sleep disturbed, by road traffic noise at night. All these figures suggest that quite a sizeable proportion of the Hong Kong population are adversely affected by road traffic noise; an issue which warrants the attention of the Government given the potential adverse health consequences.

While it is tempting to compare the Hong Kong estimates with those of other places and countries, it has been underscored in this report that very few data are currently available for comparison because most of the previous studies were undertaken at a time when there was no standardized questions and no adequate attention was given to sampling strategy and data quality (Fields et al., 2001).

In comparison with those using similar methodology, it is observed that the annoyance response of the Hong Kong population seems to be not as strong as Miedema's. The Hong Kong response curve is nonetheless comparable to those derived for two Vietnamese cities.

It is intriguing to speculate why there is a discrepancy between the response observed in Hong Kong and those obtained previously in Europe. Whether or not the discrepancy is culturally related or coping behavior modified are issues awaiting further investigation. Previous sociological studies have demonstrated that the Hong Kong population are more tolerant to high density living. One cannot dismiss the possibility that the less strong reaction can be attributed to window closing and air conditioning which magnify the indoor outdoor noise difference and reduce indoor noise exposure. The study team further observed that window closing and air conditioning is income-biased and no policy or standard should be contemplated without considering the differential effects on a particular class of the society that is relatively deprived and vulnerable.

The study also explored and elucidated factors which may intensify or moderate annoyance or sleep disturbance reactions. The results for noise annoyance and sleep disturbance are broadly similar. The study has ascertained, as in similar previous studies, that noise exposure only plays a small role in invoking annoyance reaction. Other non-acoustic factors are more important. According to the results of the binary logistic regression analysis, the most important factor which makes one highly annoyed and/or sleep disturbed is noise sensitivity. On the other hand, factors which can moderate and reduce annoyance reaction and sleep disturbance include satisfaction with the neighborhood environment and having access to a quiet room in the dwelling. The latter two factors have been previously reported in the literature, highlighting the fact that human response depends not only on the exposure at the place of residence but also in the surrounding environment. It is noteworthy that most of the socio-economic factors, such as age, gender, education and income, have very little, if not absolutely no, effect on human annoyance and sleep disturbance. It should also been noted that window closing has been found to be intensifier of annoyance and sleep disturbance reactions. No definitive explanation can be given because window closing can be the causative factor as well as the outcome. Statistical analyses can only determine the association between the two but not which is the causal factor. Again this is another area which merits further investigation.

To conclude, the study has ascertained that road traffic noise is a problem with possible health effects in Hong Kong. A sizeable proportion of the population is adversely affected. There is some indication that the annoyance and sleep disturbance responses are not as strong as those reported by Miedema. However, the Hong Kong response is comparable to those reported for two Vietnamese cities. The study has also ascertained that human response is determined only to a small extent by noise exposure. It is determined by several other non-acoustic factors. These findings call for careful rethinking of the approach to manage the acoustic environment – whether or not it should be based on reducing noise exposure alone.

The study is the first systematic survey of the health effect of transportation noise in Hong Kong. It is among one of the very few of its kind in the world. Findings of the study are significant both locally and internationally. The estimates obtained in this study are reliable, and findings sound because of the scientific rigor in questionnaire design and sampling. All these findings can contribute significantly to policy making and to the scientific community. They are essential for the creation of a sustainable urban environment of which the acoustic environment is a vital component.

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Appendix 4: Procedures of thematic household survey

The following is an excerpt from a document of The Census and Statistics Department of the Hong Kong SAR Government concerning the Thematic Household Survey.

1. The Thematic Household Survey (THS) covers the land-based non-institutional population of Hong Kong. The following categories of people are excluded:

   (a) inmates of institutions; and
   (b) persons living on board vessels.

   This survey covers around 95% of the Hong Kong Resident Population (i.e. including both Usual Residents and Mobile Residents).

2. The THS is based on a sample of quarters selected from all permanent quarters and quarters in segments which are for residential and partially residential purposes in Hong Kong in accordance with a scientifically designed sampling scheme. The sampling units are permanent quarters in built-up areas and segments in non-built-up areas.

3. The survey made use of the frame of quarters maintained by the Census and Statistics Department as the sampling frame. The frame consists of two parts: (i) Register of Quarters (RQ) and (ii) Register of Segments (RS). The RQ contains records of all addresses of permanent quarters in built-up areas, including urban areas, new towns and other major developed areas. Each unit of quarters is identified by unique address with details such as street name, building name, floor number and flat number.

4. The RS contains records of area segments in non-built-up areas which are delineated by relatively permanent and identifiable landmarks such as footpath and river. There are about 10 quarters in each segment. The use of segments as the sampling unit in non-built up areas is necessary since the quarters in these areas may not have clear addresses and cannot readily be identified individually.

Appendix 5: Trial study

1. Introduction

As developed by ICBEN Team 6, the ISO Technical Specification 15666 (ISO/TS15666:2003), written in English, provides international standardized specifications on questions, response scales and key aspects for the assessment of noise annoyance by the means of social surveys. The internationally standardized specifications allow comparisons of community responses to environmental noises between different countries. This forms a basis to understand how cultural differences influence responses to noise, so as to establish international noise criteria and international regulations to transportations crossing borders. The ISO specifications have already been tested and standardized in 9 linguistic regions, including English, Dutch, French, German, Hungarian, Japanese, Norwegian, Spanish and Turkish.

Ma and her research team conducted a study in 2003 to construct the noise survey questions and noise annoyance scale in Mandarin based on the ICBEN research method (Ma et al., 2003; Yano & Ma, 2004). In Hong Kong, the official language is Cantonese. As no study on the ISO specifications has been done for Cantonese in the Hong Kong environment, the study team has conducted a trial study to construct the noise survey questions and noise annoyance scale in Cantonese, based on Ma's research method.

2. Objectives

This trial study aims to (a) find out 5 Cantonese modifiers that describe the response level of noise, on a 5-point verbal scale and equal to the standardized English modifiers, namely "Not at all", "Slightly", "Moderately", "Very" and "Extremely"; (b) (i) apply the 5 Cantonese modifiers into the ISO questions; (ii) test, with the application of Cantonese modifiers, if the respondents understand and are able to respond to the question; (iii) try out the Show Card of the ISO questions on a 0 to 10 and a 1 to 5 annoyance response scale.

3. Methodology

In the first part to find out 5 Cantonese modifiers describing the response level of noise on a 5-point verbal scale, the procedures are as follows: (1) Based on Ma's study (Ma, 2003), select the Mandarin modifiers that can apply to Cantonese. Also, brainstorm the commonly used modifiers in Cantonese. A total of 22 Cantonese modifiers are chosen; (2) On the 5-point scale, respondents are asked to select, in the order of, a modifier that describes the most quiet environment on scale 1; a modifier that describes the noisiest environment on scale 5; a modifier that describes the environment between the most quiet and most noisiest on scale 3; a modifier that describes the environmental between 5 and 3 on scale 4; a modifier that describes the environment between 1 and 3 on scale 2.

In the second part to test out the ISO questions in Cantonese, the procedures are as follows: (1) The 5 Cantonese modifiers selected in the first part are applied to the ISO annoyance response question on a 5-point verbal scale; (2) Together with (1) 2 other ISO questions, annoyance response at night on a 11-point numeric scale and sleep disturbance response on a 11-point numeric scale, are also asked to test the clarity of the Cantonese ISO questions.

This trial study was held within the campus of the Chinese University of Hong Kong (CUHK). All of the respondents are 18 years old or above and speaks Cantonese. The respondents are mainly the staff and students of CUHK. A small portion of the respondents are general public visiting the CUHK.

The first part of the study was held during August 7-10, 2009 from 09:00 am to 05:00 pm, and a total of 151 cases have been collected. The second part of the study was held during August 18-20, 2009 from 09:00 am to 05:00 pm, and a total of 140 cases have been collected.

4. Findings

In the first part, out of the 22 Cantonese modifiers, the 5 Cantonese modifiers that have the highest numbers of response are: "完全唔(嘈)", "有 D(嘈)", "(嘈)", "好(嘈)" and "極之(嘈)" (Table 1).

In the second part, the 5 selected Cantonese modifiers aforementioned are then applied to the ISO annoyance response question on a 5-point verbal scale. All of the respondents understand clearly the question, and are able to distinguish and choose between the 5 selected Cantonese modifiers that best describes their situation. For the other two ISO questions (annoyance response at night on a 11-point numeric scale and sleep disturbance response on a 11-point numeric scale), all of the respondents understand clearly the questions.

5. Applications

As tested in the trial study, (a) 5 Cantonese modifiers are selected and (b) (i) applied to the ISO question which is used in the thematic household survey; (ii) The respondents found that the way how the 5 Cantonese modifiers are put on a 5-point scale is understandable; the respondents have no problem in choosing an answer to the ISO question with the assistance of show cards. Hence, no amendments have been made on the two ISO questions (annoyance response at night on a 11-point numeric scale and sleep disturbance response on a 11-point numeric scale), which have been used in the thematic household survey later on.

	5-point Scale		Most quiet				Most noisiest
			1st level	2nd level	3rd level	4th level	5th level
1	完全唔(嘈)	Not at all	**95**	2	0	0	0
2	一 D 都唔(嘈)		34	2	0	0	0
3	唔(嘈)		10	6	1	0	0
4	幾乎唔(嘈)		0	12	1	0	0
5	好似有 D(嘈)		2	15	2	1	0
6	稍爲有 D (嘈)		0	16	1	0	0
7	有少少(嘈) 或有 DD(嘈)		2	17	4	1	0
8	唔係點(嘈)		1	5	1	0	0
9	有 D(嘈)	Slightly	**3**	**25**	10	2	0
10	唔係好(嘈)		0	14	2	2	0
11	比較(嘈)		0	6	15	2	0
12	實在有 D(嘈)		1	2	7	1	0
13	(嘈)	Moderately	0	4	**33**	1	0
14	相當(嘈)		0	4	9	16	2
15	幾(嘈)		0	2	23	4	0
16	特別(嘈)		0	0	3	13	1
17	好(嘈)	Very	2	5	9	**30**	1
18	十分(嘈)		0	5	10	16	3
19	實在好(嘈)		0	4	6	22	15
20	太(嘈)		1	4	3	9	6
21	非常(嘈)		0	1	10	27	7
22	極之(嘈)	Extremely	0	0	1	4	**116**
		N	151	151	151	151	151

Table 1: Result of 22 modifiers from the trial study

Appendix 8: Questionnaire and show cards in English and Cantonese

Please refer to the following pages.

MOV Data Collection Center Ltd.

Tel: 3900 1194

RESTRICTED WHEN ENTERED WITH DATA ASSESSIBLE TO AUTHORIZED PERSONS ONLY

|EDIT _______ |CARD 1........(1)
|CODE ______ |JOB NO........(2-5)
|CHECK _____ |Q'NAIRE NO ..(6-9)

H09078318 Thematic Household Survey on Environmental Noise Issues, Utilisation of Services Provided by Managed Care Organisations and Studying Outside Hong Kong in 2009

Quarter Contact name:________________ (Member no.____) Contact tel. no.:________________________

No. of visits	1	2	3	4	5	6
Interviewer no.						
Date						
Time start						
Time end						
Mode of interview: H/H visit .... / Telephone ..	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐
Result						
No. of persons enumerated						

Quarter Contact name:________________ (Member no.____) Contact tel. no.:________________________

No. of visits	1	2	3	4	5	6
Interviewer no.						
Date						
Time start						
Time end						
Mode of interview: H/H visit .... / Telephone ..	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐
Result						
No. of persons enumerated						

Quarter Contact name:________________ (Member no.____) Contact tel. no.:________________________

No. of visits	1	2	3	4	5	6
Interviewer no.						
Date						
Time start						
Time end						
Mode of interview: H/H visit .... / Telephone ..	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐
Result						
No. of persons enumerated						

Enumeration result:

(1) EN = Enumerated
(2) NC = Non-Contact
(3) NR = Refusal
(4) ND = Non-Domestic
(5) MER = MERged
(6) DEM = DEMolished
(7) MP = Military Personnel
(8) PE = Partially Enumerated
(9) UN = Unoccupied
(10) INS = Institution

RESTRICTED WHEN ENTERED WITH DATA ASSESSIBLE TO AUTHORIZED PERSONS ONLY

S/N No.: | | | | | | | | |

Introduction: Good morning/afternoon/evening, my name is (read out name and show the identity card), an interviewer from MOV Data Collection Center Ltd. We are commissioned by Census & Statistics Department to conduct a survey to collect information from the Hong Kong residents on environmental issues, utilisation of services provided by Managed Care Organisations and studying outside Hong Kong. The information is useful to the Government for policy formulation. Your data collected will be kept in strict confidence. Thank you for your cooperation.

A. Quarters Information

A1 **Show card**
Which type of quarters do you live in?

Public rental housing (including the rental flats of Housing Authority and Housing Society)	1	☐
Housing Authority Tenants Purchase Scheme/ Buy-or-rent Option Scheme blocks (excluding premium-paid flats)	2	☐
Housing Authority Home Ownership Scheme/ Private Sector Participation Scheme/ Middle Income Housing Scheme blocks (excluding premium-paid flats)	3	☐
Housing Society Flat for Sale Scheme blocks (excluding premium-paid flats)	4	☐
Housing Society Sandwich Class Housing Scheme blocks (excluding premium-paid flats)	5	☐
Private residential flats (including Housing Society Urban Improvement Scheme blocks and premium-paid government subsidized flats)	6	☐
Other permanent housing (including hotels, hostels, dormitories and other residential flats and staff quarters in non-domestic buildings)	7	☐
Temporary housing (including rooftop structures, mobile dwellings, wooden houses and non-domestic purpose areas)	8	☐
Institutional housing	9	☐-End interview
Others (please specify):		

A2 [Record the floor no. of this quarter] | | | floor

A3 How many households are there in this quarters? A household is defined as a group of people who live and dine together in a quarters. They may not be relatives among themselves. A person who takes care of his/her daily necessities alone will also be classified as a household.

No. of households.......... | | |

Each household - Household I / II / III / IV / V

Ask household head for A4-A7. If different respondent is interviewed, please repeat the introduction.
Read out: Now, I would like to ask for some information about (you/ your family).

A4 Does your household rent or own this house/flat?

Owner occupied	1	☐
Tenant		
- Sole-tenant	2	☐
- Co-tenant	3	☐
- Main tenant	4	☐
- Sub-tenant	5	☐
Provided by employer	6	☐
Rent-free (e.g. belongs to relative, no need to pay any rent or living expenses; help others to look after and no need to pay rent, etc)	7	☐
Others (please specify):		

A5 Excluding live-in foreign domestic helper, how many members who are Hong Kong residents usually live in this household? I am referring to members who have lived in Hong Kong for at least 1 month in the past 6 months or will live in Hong Kong for at least 1 month in the coming 6 months, and usually stay in this household.

No. of family members (Excluding live-in foreign domestic helper).......... | | |

A6 Is there any live-in foreign domestic helper in this household? [If yes] How many?

Yes: No. of live-in foreign domestic helper.......... | | |
No.......... 99 ☐

A7 Excluding live-in foreign domestic helper, what is the relationship of each household member with you?	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Nick name						
Self/ Household head	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Spouse		2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Son/ daughter		3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
Parents		4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Brother/ sister		5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
Parents-in-law		6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
Brother/ sister-in-law		7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
Son/ daughter-in-law		8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
Grandson/ granddaughter		9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
Grandparent/grandparent-in-law		10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
Other relatives (Same generation)		11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
Other relatives (Older generation)		12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
Other relatives (Younger generation)		13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
Others (please specify):		________	________	________	________	________

B. Household Member Information

Invite each household member who live for at least one month in this household in the past 6 months or will live for at least one month in the next 6 months for interview.

B1 (Record gender)	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Male	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Female	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

B2 How old are you? (Count in full years, "0" if not yet reached 1 year old)	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Age	________	________	________	________	________	________

B3 In the past 6 months, what was the total amount of time you spent in Hong Kong?	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Less than 1 month	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Less than 3 months but at least 1 month	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
3 months or above	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐

B4 In the coming 6 months, what is the total amount of time you will spend in Hong Kong?	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Less than 1 month	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Less than 3 months but at least 1 month	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
3 months or above	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐

If B3 and B4≠3, continue with B5; otherwise skip to Part C.

B5 Are you a Hong Kong permanent resident?	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Yes	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
No	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

C. Environmental Issues (Ask only one randomly selected household member aged 18 and over (B.2≧18), other household members skip to Part D)

Base on B.2, list all household members aged 18 and over in the table below starting from the oldest to the youngest.

Member no.	Age	1	2	3	4	5	6	7	8
( )		1	2	1	3	4	2	6	7
( )		1	2	2	1	2	5	5	1
( )		1	1	3	2	3	4	7	4
( )		1	1	2	4	1	6	4	6
( )		1	2	1	1	5	6	2	5
( )		1	1	2	4	5	3	1	3
( )		1	1	3	3	3	1	7	2
( )		1	2	1	2	1	4	3	8

Record the randomly selected member - Member 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8

Invite the randomly selected member for interview and repeat introduction.

<u>Read out</u>: First I would like to ask you some questions about your estate/ street block.

C1 **<u>Show card</u>**
Looking at this card, which words describe how satisfied you are with this estate/ street block as a place to live?

Highly dissatisfied	1	☐
Dissatisfied	2	☐
Neither satisfied or dissatisfied	3	☐
Satisfied	4	☐
Highly satisfied	5	☐

C2 Could you give a short description of up to three negative aspects of living in this estate/ street block?
(Record respondent's answers and assign codes according to the codeframe)

1. ______________________________ (   )
2. ______________________________ (   )
3. ______________________________ (   )
4. ☐ [Interviewer to mark a [√] in this box if any type of noise is mentioned in one of the 3 answers above.]

C3 Could you give a short description of up to three positive aspects of living in this estate/ street block?
(Record respondent's answers and assign codes according to the codeframe)

1. ______________________________ (   )
2. ______________________________ (   )
3. ______________________________ (   )
4. ☐ [Interviewer to mark a [√] in this box if any type of noise is mentioned in one of the 3 answers above.]

<u>Read out</u>: The following question uses a 0 to 10 opinion scale for how much various sources of noise bother, disturb or annoy you when you are here at home. If you are not at all annoyed, choose 0; if you are extremely annoyed, choose 10; if you are somewhere in between, choose a number between 0 and 10.

C4 **<u>Show card</u>**
[Point to the show card] Thinking about the last 12 months or so, when you are here at home, what number from 0 to10 best shows how much you are bothered, disturbed, or annoyed by the following noises? [Show card and read out sources]

Sources	Not at all										Extremely	Not answered	Not heard such noises
a. Road traffic	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
b. MTR, trains or LRT	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
c. Aircraft	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
d. Industries/ factories/ machineries	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
e. Business activities	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
f. Construction/ demolition	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
g. Renovation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
h. Neighbour's air conditioning	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
i. Neighbours	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
j. Playgrounds/ sportsground	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
k. Any animals outside	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
l. Others (please specify): ____________	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐

C5 **Show card**
How often have you experienced the following as a result of noise from outside your home?
[Show card and read out each statement]

Statements	Never	Sometimes	A lot	Nearly all the time	Not answered
a. Disturbance of telephone conversation.......	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐
b. Disturbance of normal conversation...........	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐
c. Disturbance of listening to TV/ radio	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐
d. Disturbance of rest and relaxation	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐
e. Disturbance by noise while concentrating on tasks, such as reading	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐

C6 **Show card**
What have you done in the past 12 months when you were bothered by outside noise while at home?
[Show card and read out each statement]

Statements	Never	Sometimes	A lot	Nearly all the time	Not answered	Not heard such noises/ Not bordered by such noises
a. Complained about noise	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐	99 ☐
b. Switched on the air conditioner	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐	99 ☐
c. Closed the windows.................................	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐	99 ☐
d. Used ear plugs in the home......................	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐	99 ☐
e. Others (please specify): __________	1 ☐	2 ☐	3 ☐	4 ☐	88 ☐	99 ☐

C7 **Show card**
Thinking about the past 12 month or so, when you were at home, how much does noise from the following sources bother, disturb, or annoy you AT NIGHT? [Show card and read out sources]

Sources	Not at all										Extremely	Not answered	Not heard such noises
a. Road traffic........................	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
b. MTR, trains or LRT...........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
c. Aircraft	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
d. Industries/ factories/ machineries	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
e. Business activities	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
f. Construction/ demolition ...	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
g. Renovation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
h. Neighbour's air conditioning	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
i. Neighbours	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
j. Playgrounds/ sportsground	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
k. Any animals outside	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
l. Others (please specify): ___________________	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐

C8 **Show card**
Thinking about the past 12 month or so, when you were here at home, how much was your SLEEP disturbed by noise from the following sources? [Show card and read out sources]

Sources	Not at all										Extremely	Not answered	Not heard such noises
a. Road traffic........................	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
b. MTR, trains or LRT...........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
c. Aircraft	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
d. Industries/ factories/ machineries.......................	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
e. Business activities	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
f. Construction/ demolition ...	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
g. Renovation	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
h. Neighbour's air conditioning.......................	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
i. Neighbours	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
j. Playgrounds/ sportsground	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
k. Any animals outside	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
l. Others (please specify): ___________________	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐

C9	Which of the following statements are applicable to the quality of your sleep in the past one month? [Read out each statement and record (No = 0; Yes = 1)]	
Statements	No	Yes
a. At night I often do not sleep at all	0 ☐	1 ☐
b. I often get up at night	0 ☐	1 ☐
c. I usually toss and turn a lot during the night	0 ☐	1 ☐
d. I wake once or more per night	0 ☐	1 ☐
e. I consider that I generally sleep very badly	0 ☐	1 ☐
f. Often it feels as if I only slept a few hours	0 ☐	1 ☐
g. I sleep often not longer than five hours	0 ☐	1 ☐
h. I think I usually sleep well at night	0 ☐	1 ☐
i. I generally go to sleep easily	0 ☐	1 ☐
j. I often lie awake in bed for more than half an hour before falling asleep	0 ☐	1 ☐
k. If I wake up at night I find it hard to get back to sleep.	0 ☐	1 ☐
l. After getting up in the morning, I usually feel well rested	0 ☐	1 ☐

C10 During the past one month on an average weekday (Monday through Friday), what time of the day/ night do you start to sleep in bed and what time do you get up? [Record the second period only if the respondent mentions it]

	Hour	Minute		Hour	Minute
a. Most often: From a.m./ p.m.	☐☐	☐☐	to a.m./ p.m.	☐☐	☐☐
b. Secondary: From a.m./ p.m.	☐☐	☐☐	to a.m./ p.m.	☐☐	☐☐

C11 How much sleep do you feel you need, in order to feel satisfactorily rested?

☐☐ hours

C12 **Show card**
Now I will read out some general statements that concern noise in your daily life. If you strongly disagree, choose 0; if you strongly agree, choose 5; if you are somewhere in between, choose a number between 0 and 5.
[Show card and read out each statement]

Statements	Strongly disagree					Strongly agree	Not answered
a. I am easily awakened by noise	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
b. I get used to most noises without much difficulty	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
c. I find it hard to relax in a place that is noisy	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
d. I am good at concentrating no matter what is going on around me	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
e. I get mad at people who make noise that keeps me from falling asleep or getting work done	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
f. When I want to be alone, it disturbs me to hear outside noise	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
g. I am sensitive to noise	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐

C13 **Show card**
Thinking about the last 12 months or so, when you are here at home, how much does noise from the following sources bother, disturb, or annoy you? [Show card and read out sources]

Sources	Not at all	Slightly	Moderately	Very	Extremely	Not answered	Not heard such noises
a. Road traffic	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
b. MTR, trains or LRT	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
c. Aircraft	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
d. Industries/ factories/ machineries	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
e. Business activities	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
f. Construction/ demolition	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
g. Renovation	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
h. Neighbour's air conditioning	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
i. Neighbours	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
j. Playgrounds/ sportsground	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
k. Any animals outside	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
l. Others (please specify): ____________	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐

Read out: This part of the questionnaire is about your health. Kindly note that some questions may be a bit sensitive and please do not mind. The information you provided will be kept in strict confidence and will be used for aggregate analysis only.

C14 **Show card**
In general would you say your health is?

Very good	1 ☐
Good	2 ☐
Fair	3 ☐
Poor	4 ☐
Very poor	5 ☐

C15 **Show card**
Compared with one year ago, how would you rate your health in general?

Much better than a year ago	1 ☐
Somewhat better than a year ago	2 ☐
About the same now as a year ago	3 ☐
Somewhat worse than a year ago	4 ☐
Much worse than a year ago	5 ☐

C16 In the last 2 weeks, have you consulted a GP or local doctor about your health, excluding medical check-up and dental?

No	0 ☐
Yes	1 ☐

C17 In the past 2 years, have you been hospitalised?

No	0 ☐
Yes	1 ☐

C18 Have you ever been diagnosed by a doctor with the following diseases? [Read out each disease]

If any diseases answered "Yes", continue with C19; otherwise skip to C20

C19 Have you been treated regularly for **[Read out each disease answered "Yes" in C18]** in the past one month? Treatment including taking medicine regularly or from time to time.

	C18		C19	
Diseases	No	Yes	No	Yes
a. Hypertension	0 ☐	1 ☐	0 ☐	1 ☐
b. Heart disease/ cardiovascular effects	0 ☐	1 ☐	0 ☐	1 ☐
c. Diabetes	0 ☐	1 ☐	0 ☐	1 ☐
d. Chronic headaches/ migraines	0 ☐	1 ☐	0 ☐	1 ☐
e. Depression/ anxiety	0 ☐	1 ☐	0 ☐	1 ☐
f. Insomnia (severe sleeping problems)	0 ☐	1 ☐	0 ☐	1 ☐
g. Peptic ulcer	0 ☐	1 ☐	0 ☐	1 ☐
h. Asthma	0 ☐	1 ☐	0 ☐	1 ☐

C20 Have you taken the following drugs in the past 1 month? [Read out each drug]

If any drugs answered "Yes", continue with C21; otherwise skip to C22

C21 How often do you take **[Read out each drug answered "Yes" in C20]?**

	C20		C21					
Drugs	No	Yes	Once a day or more often	More than once a week but not daily	Once a week	More than once a month but less than once a week	Once a month	Less than once a month
a. Hypertension drugs	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
b. Cardiovascular drugs	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
c. Antidiabetic drugs	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
d. Sleeping pills	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
e. Tranquilizer	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐

C22 Without using any hearing aid, do you have any problems or difficulties with your sense of hearing?

No → **Skip to C25**	0 ☐
Yes → **C23**	1 ☐

If answered "Yes" (C22=1), continue with C23; otherwise skip to C25

C23 Please specify the condition of hearing problems or difficulties. Any others? Any others?
(Record respondent's answers and assign codes according to the codeframe)

____ (   )

____ (   )

____ (   )

C24	Do you need any hearing aid?	
	No	0 ☐
	Yes	1 ☐

Read out: Next, I would like to ask you some questions about your home and your working status.

C25	What is your current employment status?	
	Yes - Full time → **C26**	1 ☐
	- Part time → **C26**	2 ☐
	No → **C28**	3 ☐

If "Yes – full time/part time" (C25=1-2), continue with C26; otherwise skip to C28

C26	Does your job require overnight shift work? Overnight shift work refers to work for at least 4 hours between 12 a.m. midnight to 6 a.m. in the morning.	
	No → **Skip to C28**	0 ☐
	Yes → **C27**	1 ☐

If answered "yes" (C26=1), continue with C27; otherwise skip to C28

C27	Do you frequently work overnight shift or work day and night shift alternatively?	
	Frequently work overnight shift	1 ☐
	Work day and night shift alternatively	2 ☐

C28	How many years have you lived in this home?	
		☐☐ years
	Less than one year	999 ☐

C29	How many ..(Read out)..are there in this household?	
	Living rooms/ dining rooms	☐☐ rooms
	Bedrooms/ maidrooms	☐☐ rooms
	Study rooms/ store rooms	☐☐ rooms
	Open-style quarters	999 ☐

C30 In an average weekday (Monday through Friday), when are you usually at home?

1 ☐ Full day

	Hour	Minute		Hour	Minute
2. From a.m./ p.m.	☐☐	☐☐	to a.m./ p.m.	☐☐	☐☐
3. From a.m./ p.m.	☐☐	☐☐	to a.m./ p.m.	☐☐	☐☐

C31	**Show card** Do you sleep with the windows closed? (Count for the whole year; if open-style quarters, count for the whole quarters)	
	Never	1 ☐
	Sometimes	2 ☐
	A lot	3 ☐
	Nearly all the time	4 ☐
	Not applicable (No window)	9 ☐

C32	**Show card** In the day time when there are people at home, do you keep the windows closed where the people are (Count for the whole year; if open-style quarters, count for the whole quarters)	
	Never	1 ☐
	Sometimes	2 ☐
	A lot	3 ☐
	Nearly all the time	4 ☐
	Not applicable (No window)	9 ☐

C33	Do you have an air conditioner in your living room/ dining room? (If open-style quarters, count for the whole quarters)	
	No	0 ☐
	Yes	1 ☐

C34	Do you have an air conditioner in your bedroom? (If open-style quarters, count for the whole quarters)	
	No	0 ☐
	Yes	1 ☐

C35	Are you taking any measures to reduce noise coming from outside?	
	Not applicable (No noise)	9 ☐
	No	0 ☐
	Yes	1 ☐
	[If yes, please specify]: ______________________________	

C36	Does your household have one or more bedrooms NOT facing roads or railways?	
	No	0 ☐
	Yes	1 ☐

C37	Can you tell me any source of noise from outside your home that bother, disturb, or annoy you? Any others? Any others? (Record respondent's answers and assign codes according to the codeframe)
	____( )
	____( )
	____( )

F. Personal data

Read out: Now we would like to ask you some personal data. Your data collected will be kept in strict confidence and will only be used for aggregated analysis.

F1 What is your current marital status?

	a	b	c	d	e	f
	Member (H/Hhead)	Member 2	Member 3	Member 4	Member 5	Member 6
Never married	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Married	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Divorced/ separated	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
Widowed	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Others (please specify):	________	________	________	________	________	________

F2 Are you attending a school/educational institute?

	a	b	c	d	e	f
	Member (H/Hhead)	Member 2	Member 3	Member 4	Member 5	Member 6
Yes → F3	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
No → F5	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

If "Yes" (F2=1), continue with F3; otherwise skip to F5.

F3 Is it a full-time (including primary schools AM and PM), part time or distance learning course?

	a	b	c	d	e	f
	Member (H/Hhead)	Member 2	Member 3	Member 4	Member 5	Member 6
Full-time (including primary schools AM and PM)	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Part-time	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Distance learning	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐

F4 Which level are you studying?

	a	b	c	d	e	f
	Member (H/Hhead)	Member 2	Member 3	Member 4	Member 5	Member 6
Primary (P.1-P.3)	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Primary (P.4-P.6)	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
Lower secondary (F.1-F.3)	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
Upper secondary (F.4-F.5)	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
Matriculation (F.6-F.7)	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
Project Yi Jin	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
Technical/ vocational training (craft course/ apprenticeship)	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
Technical/ vocational training (certificate courses)	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
Tertiary education: (Sub-degree courses)	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
Tertiary education: (Undergraduate courses)	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
Tertiary education: (Master's / doctor's courses)	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐

F5 What is the highest class/level of education you have completed? (Please fill in the highest class/level of education completed)

	a	b	c	d	e	f
	Member (H/Hhead)	Member 2	Member 3	Member 4	Member 5	Member 6
No schooling, illiterated	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Attended some classes, know a few words	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Kindergarten	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
Primary (P.1-P.3)	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Primary (P.4-P.6)	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
Lower secondary (F.1-F.3)	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
Upper secondary (F.4-F.5)	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
Matriculation (F.6-F.7)	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
Project Yi Jin	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
Technical/ vocational training (craft course/ apprenticeship)	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
Technical/ vocational training (certificate courses)	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
Tertiary education: (Sub-degree courses)	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
Tertiary education: (Undergraduate courses)	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
Tertiary education: (Master's / doctor's courses)	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐

F6 Are you a one-way permit holder coming from the Mainland to reside in Hong Kong?
If "Yes", probe: "Have you been to Hong Kong for 7 years?"

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Yes						
- 7 years or above	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
- Below 7 years	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
No	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐

If aged 15 or above, continue with F7; otherwise skip to F14

F7 Did you have a full-time or part-time job in the past 7 days? Running own business or assisting in family business without pay are also included. Please count any work for an hour or above.

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Yes → F8	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
No → F10	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

If "Yes" (F7=1) , continue with F8; otherwise skip to F10

F8 What industry are you engaged in?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Agriculture, fishing, mining & quarrying	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Manufacturing	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Electricity, gas and water supply, and waste management	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
Construction	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Import/export trade and wholesale	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
Retail	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
Accommodation and food services	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
Transportation, storage, postal and courier services	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
Information and communications	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
Financing and insurance	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
Real estate	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
Professional and business services	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
Public administration	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
Social and personal services	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐
Others (please specify):	________	________	________	________	________	________

F9 What is your occupation?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Managers and administrators	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Professionals	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Associate professionals	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
Clerks	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Service workers and shop sales workers	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
Skilled agricultural and fishery workers	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
Craft and related workers	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
Plant and machine operators and assemblers	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
Elementary occupations	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
Others (please specify):	________	________	________	________	________	________

Skip to F14

F10 If someone offered you a job in the past 7 days, were you immediately available for work?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Yes → F12	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
No → F11	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

If "No" (F10=2) , continue with F11; otherwise skip to F12

F11 Why were you not available?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Attendance at educational institutions → F14	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Engagement in household duties → F14	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Retirement → F14	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
Illness (Chronic) → F14	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Illness (Non-chronic) → F12	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
Others (please specify):	________	________	________	________	________	________

If "Non-chronic illness" (F11=5) , continue with F12; otherwise skip to F14

F12 Were you seeking work during the past 30 days?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Yes → F14	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
No → F13	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

If "No" (F12=2) , continue with F13; otherwise skip to F14

F13 Why did you not seek work?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Believed no work is available	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Waited to take up a new job	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Expected to return to original job	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
Would start business at subsequent date	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Others (please specify):	________	________	________	________	________	________

F14 **Show card**

Which of the followings are your income sources? Any others? **(Allow multiple answers)** [MA]

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Employment salary/wages	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
Bonus	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
Housing allowance	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
Provident fund/Pensions	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
Comprehensive Social Security Assistance	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
Disability allowance	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
Old age allowance	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
Interest/dividend	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
Financial support from relatives/friends living apart	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
Rental income	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
Education grant (excluding loan)	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
Others (please specify):	________	________	________	________	________	________
No income	97	97	97	97	97	97

If having any income sources (F14≠97), continue with H15; otherwise skip to F16 for household head, skip to instruction after F16 for other household members.

F15 **Show card**
Including all your income sources and MPF contribution, what is your average monthly personal income?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
$1 - $999	20 ☐	20 ☐	20 ☐	20 ☐	20 ☐	20 ☐
$1,000 – $1,999	19 ☐	19 ☐	19 ☐	19 ☐	19 ☐	19 ☐
$2,000 – $2,999	18 ☐	18 ☐	18 ☐	18 ☐	18 ☐	18 ☐
$3,000 – $3,999	17 ☐	17 ☐	17 ☐	17 ☐	17 ☐	17 ☐
$4,000 – $4,999	16 ☐	16 ☐	16 ☐	16 ☐	16 ☐	16 ☐
$5,000 – $5,999	15 ☐	15 ☐	15 ☐	15 ☐	15 ☐	15 ☐
$6,000 – $6,999	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐
$7,000 – $7,999	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
$8,000 – $8,999	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
$9,000 – $9,999	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
$10,000 – $12,499	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
$12,500 – $14,999	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
$15,000 – $19,999	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
$20,000 – $24,999	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
$25,000 – $29,999	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
$30,000 – $39,999	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
$40,000 – $49,999	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
$50,000 – $59,999	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
$60,000 – $69,999	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
$70,000 or above	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐

F16 **Ask household head only**
Show card
Including all your income sources and MPF contribution, what is your average monthly household income in total?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
$1 - $999	20 ☐					
$1,000 - $1,999	19 ☐					
$2,000 – $2,999	18 ☐					
$3,000 - $3,999	17 ☐					
$4,000 – $4,999	16 ☐					
$5,000 – $5,999	15 ☐					
$6,000 – $6,999	14 ☐					
$7,000 – $7,999	13 ☐					
$8,000 – $8,999	12 ☐					
$9,000 – $9,999	11 ☐					
$10,000 – $12,499	10 ☐					
$12,500 – $14,999	9 ☐					
$15,000 – $19,999	8 ☐					
$20,000 – $24,999	7 ☐					
$25,000 – $29,999	6 ☐					
$30,000 – $39,999	5 ☐					
$40,000 – $49,999	4 ☐					
$50,000 – $59,999	3 ☐					
$60,000 – $69,999	2 ☐					
$70,000 or above	1 ☐					
No income (please state reason)	97 ☐					

— Thank respondent and read out —
In order to ensure the quality of data, our QA department may contact you for a short sample quality check at a later time. Thank you in advance for your cooperation.

To facilitate our future planning of this survey and enhance our service, please let us have your views on the data collection method of this survey by furnishing us the following information. The information you provided will be of great value for us to review the survey operation.

F17 **Show card**
Assuming that your household was selected in the next round of this survey, which of the following mode will you prefer most to submit this survey questionnaire?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
(a) On-line submission	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
(b) Postal return...	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
(c) Face-to-face interview	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
(d) Others (please specify):	______	______	______	______	______	______

F18 **Show card**
Assuming that your household was selected in the next round of this survey, which of the following mode will you prefer most to submit this survey questionnaire if only information on the living quarters and gender and age of the household members is required?

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
(a) On-line submission	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
(b) Postal return...	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
(c) Face-to-face interview	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
(d) Others (please specify):	______	______	______	______	______	______

F19 (Record mode of interview)

	a	b	c	d	e	f
	Member (H/H head)	Member 2	Member 3	Member 4	Member 5	Member 6
Household visit						
- Self-reporting (V/S)	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
- Proxy-reporting (Only applicable when respondent has difficulty in answering questions in person due to his/ her old age or intellectual ability)(V/P)	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
[Record member number for person who provide proxy answer]	______	______	______	______	______	______
- Proxy-reporting for Part E (Only applicable when respondent has difficulty in answering questions in person due to his/ her old age or intellectual ability)(V/P)	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
[Record member number for person who provide proxy answer]	______	______	______	______	______	______
Telephone						
- Self-reporting (T/S).................................	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
- Proxy-reporting (Only applicable when respondent has difficulty in answering questions in person due to his/ her old age or intellectual ability)(T/P)	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
[Record the serial number of proxy respondent]	______	______	______	______	______	______
- Proxy-reporting for Part E (Only applicable when respondent has difficulty in answering questions in person due to his/ her old age or intellectual ability)(T/P)	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
[Record the serial number of proxy respondent]	______	______	______	______	______	______

— Thank respondent again and end interview, and read out —
Thank you very much for your co-operation again. Goodbye!

MOV Data Collection Center Ltd. 米奧特資料搜集中心

電話號碼：3900 1194

填入數據後即成 **限閱文件**
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|EDIT ________ |CARD 1 .... (1)
|CODE _______ |JOB NO .... (2-5)
|CHECK ______ |Q'NAIRE NO. (6-9)
|______________________________

H09078318 二零零九年有關環境噪音事宜、使用醫療集團服務及在香港以外地方就讀的情況的主題性住戶統計調查

____

單位 聯絡人姓名：_______________ (成員編號 ____) 聯絡電話號碼：_______________________

到訪次數	1	2	3	4	5	6
訪問員號碼						
日期						
開始時間						
結束時間						
訪問形式: 上門........ 電話........	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐
訪問結果						
成功訪問人數						

單位 聯絡人姓名：_______________ (成員編號 ____) 聯絡電話號碼：_______________________

到訪次數	1	2	3	4	5	6
訪問員號碼						
日期						
開始時間						
結束時間						
訪問形式: 上門........ 電話........	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐
訪問結果						
成功訪問人數						

單位 聯絡人姓名：_______________ (成員編號 ____) 聯絡電話號碼：_______________________

到訪次數	1	2	3	4	5	6
訪問員號碼						
日期						
開始時間						
結束時間						
訪問形式: 上門........ 電話........	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐	1 ☐ 2 ☐
訪問結果						
成功訪問人數						

訪問結果：

(1) EN = Enumerated (完成整個訪問)
(2) NC = Non-Contact (無人應門)
(3) NR = Refusal (拒絕訪問)
(4) ND = Non-Domestic (非住宅用途)
(5) MER = MERged (合併單位)
(6) DEM = DEMolished (已拆卸)
(7) MP = Military Personnel (軍方人員)
(8) PE = Partially Enumerated (部分完成)
(9) UN = Unoccupied (空置)
(10) INS = Institution (院舍)

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只有獲授權人士可閱讀本文件內容

檔案編號: | | | | | | | | |

<u>引言：</u> 早晨 / 午安 / 晚安，我姓 (講出姓氏及出示證件)，係米奧特資料搜集中心 訪問員。我 受<u>政府統計處</u>委託進行一項統計調查，目的係搜集有關<u>公眾對環境e 意見，以及使用醫療集團服務及在香港以外地方就讀e 情況等資料</u>，所得資料對政府制訂有關政策非常重要。你所提供e 資料會絕對保密。多謝你e 合作。

A. 住宅單位資料

A1 <u>示咭</u>
請問你呢個住宅單位係屬於邊一類型 房屋呢？

公營租住房屋 (包括房屋委員會及房屋協會租住單位)	1 ☐
房屋委員會租者置其屋計劃 / 可租可買計劃 出售單位 (<u>不</u>包括已補地價的單位)	2 ☐
房屋委員會 居者有其屋計劃 / 私人參與計劃 /中等入息家庭房屋計劃 屋宇單位 (<u>不</u>包括已補地價的單位)	3 ☐
房屋協會住宅發售計劃 屋宇單位 (<u>不</u>包括已補地價的單位)	4 ☐
房屋協會夾心階層住屋計劃 屋宇單位 (<u>不</u>包括已補地價的單位)	5 ☐
私人住宅單位 (包括房屋協會市區改善計劃 屋宇單位、已補地價的資助出售單位及多層樓宇房屋單位)	6 ☐
其他永久性建築物 (包括在酒店、旅舍、宿舍和其他非住宅建築物內的住宿地方及員工宿舍)	7 ☐
臨時房屋(包括天台建築物、流動居所及臨時建築物)	8 ☐
公共機構/社團院舍	9 ☐ - 結束訪問
其他（請註明）：	

A2 [記錄住戶住緊幾多樓] ☐☐ 樓

A3 呢度總共有幾多伙人住呢？<u>一伙人係指一班住 同一個單位，同食同住 人士</u>。佢 唔一定有親戚關係。自己單獨安排生活所需 人士亦算係一伙。

有幾多伙人住 ☐☐ 伙

每伙人分別填問卷 - 伙 **I / II / III / IV / V**

A4-A7由各伙的戶主作答。若轉換了訪問對象，重覆引言。
<u>讀出：</u> 而家我想知道關於 (你呢伙人/你屋企) 一 資料。

A4 請問而家呢個單位係你哋買嘅、租嘅、抑或其他呢？

買	1 ☐
租	
- 全租	2 ☐
- 合租	3 ☐
- 二房東	4 ☐
- 三房客	5 ☐
僱主提供	6 ☐
免租 (例如單位是親屬物業，並不用支付任何租金或生活費用；單位屬代爲看管而不用付租等)	7 ☐
其他（請註明）：	

A5 <u>唔計留宿嘅外籍家庭傭工</u>，(你呢伙人/你屋企) 總共有幾多位家庭成員係香港居民呢？我係指過去六個月<u>總共有一個月或以上</u>，或者未來六個月總共有一個月或以上通常喺呢個單位度住嘅家庭成員。

有幾多家庭成員(不包括留宿嘅外籍家庭傭工) ☐☐ 人

A6 (你呢伙人/你屋企) 有冇<u>留宿嘅外籍家庭傭工</u>? [如有] 咁有幾多位呢?

有: 有幾多留宿嘅外籍家庭傭工 ☐☐ 人
冇 99 ☐

A7 <u>唔計留宿嘅外籍家庭傭工</u>，請你話俾我聽 (你呢伙人/你屋企)ɐ 家庭成員同你係乜嘢關係呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
稱呼						
自己/戶主	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
配偶		2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
子女		3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
父母		4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
兄弟姊妹		5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
配偶父母		6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
嫂子／姐夫／妹夫／弟婦		7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
女婿／媳婦		8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
孫子孫女		9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
祖父母／配偶祖父母		10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
其他親戚(同輩)		11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
其他親戚(長輩)		12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
其他親戚(後輩)		13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
其他 (請註明)：		________	________	________	________	________

B. 家庭成員資料

個別邀請過去 **6** 個月或未來 **6** 個月有 **1** 個月或以上 度住 家庭成員 **(**以下簡稱家庭成員**)** 作答。

B1 (記錄性別)

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
男	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
女	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

B2 請問你今年幾多歲？ (以足歲計，未夠一歲的爲"0")

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
年齡	______歲	______歲	______歲	______歲	______歲	______歲

B3 過去6個月內，你總共有幾多時間喺香港呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
少過1個月	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
少過3個月但最少1個月	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
3個月或以上	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐

B4 未來6個月內，你總共預算會有幾多時間喺香港呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
少過1個月	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
少過3個月但最少1個月	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
3個月或以上	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐

若B3及B4≠3，續問 B5；否則跳至C部分。

B5 請問你係唔係香港永久性居民呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
係	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
唔係	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

C. 環境事宜 (只問一位經隨機抽選的18歲或以上家庭成員 (B.2 18)，其他家庭成員跳至D部分)

根據**B2**，將所有**18**歲或以上家庭成員，由大至細列於下表。

成員編號	年歲	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
( )		1	2	1	3	4	2	6	7
( )		1	2	2	1	2	5	5	1
( )		1	1	3	2	3	4	7	4
( )		1	1	2	4	1	6	4	6
( )		1	2	1	1	5	6	2	5
( )		1	1	2	4	5	3	1	3
( )		1	1	3	3	3	1	7	2
( )		1	2	1	2	1	4	3	8

記錄隨機抽選中的家庭成員 - 成員 **1 / 2 / 3 / 4 / 5 / 6 / 7 / 8**

邀請該家庭成員接受訪問，然後重覆引言。

<u>讀出</u>：首先想問你幾條有關你呢個屋邨 / 呢條街嘅問題。

C1 <u>示咭</u>

請睇住呢張咭。作爲居住地方，你對呢個屋邨 / 呢條街有幾滿意呢？

好唔滿意........................ 1 ☐
唔滿意........................ 2 ☐
冇乜話滿唔滿意........................ 3 ☐
滿意........................ 4 ☐
好滿意........................ 5 ☐

C2 你可唔可以簡單咁講出，住喺呢個屋邨／呢條街嘅三個壞處呢？(記錄受訪者答案並按答案編碼表填下有關編碼)

1. ________________________ ( )
2. ________________________ ( )
3. ________________________ ( )
4. ☐ [如上述任何一項回應是與噪音有關，訪問員須在此方格加上 [√] 號。]

C3 你可唔可以簡單咁講出，住喺呢個屋邨／呢條街嘅三個好處呢？(記錄受訪者答案並按答案編碼表填下有關編碼)

1. ________________________ ( )
2. ________________________ ( )
3. ________________________ ( )
4. ☐ [如上述任何一項回應是與聲音有關，訪問員須在此方格加上 [√] 號。]

<u>讀出</u>：以下嘅問題，我想請你用0至10嘅尺度嚟表示當你喺屋企嘅時候，某種噪音對你嘅打擾、干擾或煩擾嘅程度有幾大。如果你完全唔受打擾、干擾或煩擾，請揀0；如果你極之受打擾、干擾或煩擾，請揀10；如果你覺得所受嘅影響介乎兩者之間，請喺0至10之間揀一個恰當嘅數字嚟表示你受打擾、干擾或煩擾嘅程度。

C4 <u>示咭</u>

[請指著示咭] 喺過去12個月內，當你喺屋企嘅時候，以下嘅噪音對你嘅打擾、干擾或煩擾程度有幾大呢？尺度入面0至10之間邊個數字最能夠表示有關噪音對你嘅打擾、干擾或煩擾程度呢？ [示咭，並讀出噪音來源]

來源	完全唔煩擾										極之煩擾	沒回答	聽唔到/唔覺有
a. 道路交通	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
b. 地鐵、火車或輕鐵	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
c. 飛機........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
d. 工業 / 工廠 / 機械........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
e. 商業活動........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
f. 建築 / 拆卸地盤........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
g. 裝修........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
h. 鄰居冷氣機........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
i. 鄰居........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
j. 公園 / 運動場........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
k. 任何戶外動物........	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐
l. 其他 (請註明): ____________	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐	88 ☐	99 ☐

C5 示咭
嚟自你屋企外面嘅噪音，有幾經常會對你造成以下嘅干擾呢？ [示咭，並讀出下列受到干擾事項]

事項	從來都冇	有時有	好多時有	差唔多所有時間都有	沒回答
a. 嘈住你電話通話	1 □	2 □	3 □	4 □	88 □
b. 嘈住你正常談話	1 □	2 □	3 □	4 □	88 □
c. 嘈住你睇電視 / 聽收音機	1 □	2 □	3 □	4 □	88 □
d. 嘈住你休息及鬆馳	1 □	2 □	3 □	4 □	88 □
e. 嘈住你集中精神做事，如閱讀等 ..	1 □	2 □	3 □	4 □	88 □

C6 示咭
喺過去12個月內，當你喺屋企受到外面嘅噪音打擾嘅時候，你有幾經常會作出以下相應嘅對策呢？
[示咭，並讀出下列應付辦法]

辦法	從來都冇	有時有	好多時有	差唔多所有時間都有	沒回答	聽唔到/唔覺有噪音打擾
a. 就有關噪音投訴	1 □	2 □	3 □	4 □	88 □	99 □
b. 開啓冷氣機	1 □	2 □	3 □	4 □	88 □	99 □
c. 關閉窗戶	1 □	2 □	3 □	4 □	88 □	99 □
d. 喺屋企戴上耳塞	1 □	2 □	3 □	4 □	88 □	99 □
e. 其他 (請註明): ________________	1 □	2 □	3 □	4 □	88 □	99 □

C7 示咭
喺過去12個月內，當你**晚上**喺屋企嘅時候，以下嘅噪音對你嘅打擾、干擾或煩擾程度有幾大呢？
[示咭，並讀出噪音來源]

來源	完全唔煩擾										極之煩擾	沒回答	聽唔到/唔覺有
a. 道路交通	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
b. 地鐵、火車或輕鐵	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
c. 飛機	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
d. 工業 / 工廠 / 機械	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
e. 商業活動	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
f. 建築 / 拆卸地盤	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
g. 裝修	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
h. 鄰居冷氣機	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
i. 鄰居	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
j. 公園 / 運動場	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
k. 任何戶外動物	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
l. 其他 (請註明): ________________	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □

C8 示咭
喺過去12個月內，當你喺屋企嘅時候，以下嘅噪音對你**瞓覺**造成嘅干擾程度有幾大呢？
[示咭，並讀出噪音來源]

來源	完全唔干擾										極之干擾	沒回答	聽唔到/唔覺有
a. 道路交通	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
b. 地鐵、火車或輕鐵	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
c. 飛機	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
d. 工業 / 工廠 / 機械	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
e. 商業活動	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
f. 建築 / 拆卸地盤	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
g. 裝修	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
h. 鄰居冷氣機	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
i. 鄰居	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
j. 公園 / 運動場	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
k. 任何戶外動物	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □
l. 其他 (請註明): ________________	0 □	1 □	2 □	3 □	4 □	5 □	6 □	7 □	8 □	9 □	10 □	88 □	99 □

C9 喺以下嘅一啲句子中，邊幾句能夠形容你喺過去一個月內嘅睡眠質素呢？
[讀出下列各句子及記下答案 (唔係= 0；係=1)]

句子	唔係	係
a. 夜晚我經常瞓唔著	0 ☐	1 ☐
b. 夜晚我經常紮醒	0 ☐	1 ☐
c. 通常我成晚都會碌來碌去	0 ☐	1 ☐
d. 每晚我都會醒一次或以上	0 ☐	1 ☐
e. 我認爲我一般都瞓得好差	0 ☐	1 ☐
f. 經常覺得只係瞓咗幾個鐘頭	0 ☐	1 ☐
g. 我經常瞓少過五個鐘頭	0 ☐	1 ☐
h. 我認爲我晚上通常瞓得好	0 ☐	1 ☐
i. 大致上我係容易瞓著	0 ☐	1 ☐
j. 我經常要清醒咁瞓喺床上半個鐘或以上先至瞓得著	0 ☐	1 ☐
k. 假如半夜紮醒，我好難再瞓得著	0 ☐	1 ☐
l. 朝頭早起身後，我通常覺得已經得到充份嘅休息	0 ☐	1 ☐

C10 喺過去一個月內，一般喺平日，即星期一至五，你通常喺日頭或者夜晚幾點開始上床瞓覺，到幾點起身呢？
[第二段時間只在受訪者提及才記錄]

	時		分			時		分	
a.通常: 從上午 / 下午					到上午 / 下午				
b.其次: 從上午 / 下午					到上午 / 下午				

C11 你覺得要瞓幾多個鐘先至感覺得到滿意嘅休息呢？

☐☐ 小時

C12 示咭
而家我會讀出一啲喺你日常生活裏面有關噪音嘅講法。如果你十分唔同意呢啲講法，請揀0；如果你十分同意呢啲講法，請揀5；如果你覺得答案係介乎兩者之間，請喺0至5之間揀一個恰當數字。
[示咭，並讀出下列每句陳述]

陳述	十分唔同意					十分同意	沒回答
a. 我好容易被噪音嘈醒	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
b. 我好容易就習慣咗大部分噪音	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
c. 喺嘈吵嘅地方，我好難休息	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
d. 唔理周圍有啲乜嘢事，我都能夠好好集中精神	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
e. 我好嬲嗰啲嘈住我瞓覺或者嘈住我做嘢嘅人	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
f. 當我想獨自一個人嘅時候，聽到外面嘅噪音就會對我做成干擾	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐
g. 我對噪音嘅反應敏感	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐

C13 示咭
以下係一條之前問過嘅問題，我想請你用另一個尺度回答。喺過去12個月內，當你喺屋企嘅時候，以下嘅噪音有幾大程度打擾、干擾或煩擾你呢？ [示咭，並讀出噪音來源]

來源	完全唔煩擾	有啲煩擾	煩擾	好煩擾	極之煩擾	沒回答	聽唔到/唔覺有
a. 道路交通	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
b. 地鐵、火車或輕鐵	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
c. 飛機	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
d. 工業 / 工廠 / 機械	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
e. 商業活動	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
f. 建築 / 拆卸地盤	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
g. 裝修	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
h. 鄰居冷氣機	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
i. 鄰居	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
j. 公園 / 運動場	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
k. 任何戶外動物	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐
l. 其他 (請註明): ________________	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	88 ☐	99 ☐

讀出：以下係一啲有關你健康嘅問題。請你唔好介意，有啲問題可能比較敏感，你所提供嘅資料會絕對保密，我哋只會作綜合分析。

C14 示咭
一般嚟講，你認爲你嘅健康有幾好呢？

非常好	1 ☐
好	2 ☐
普通	3 ☐
唔好	4 ☐
非常差	5 ☐

C15 示咭
同一年前比較，你覺得你而家嘅健康情況係好咗、差咗，抑或係差唔多呢？

比一年前好得多	1 ☐
比一年前好啲	2 ☐
同一年前差唔多	3 ☐
比一年前差啲	4 ☐
比一年前差得多	5 ☐

C16 喺過去兩星期內，你有冇因健康問題去睇醫生呢？包括**普通科、專科**或中醫，但身體檢查、牙醫、或生育唔計。

冇	0 ☐
有	1 ☐

C17 喺過去兩年內，你有冇因爲健康問題入住過醫院呢？ (身體檢查、牙醫、或生育唔計)

冇	0 ☐
有	1 ☐

C18 醫生有冇曾經診斷過你有以下嘅病呢？ [讀出下列病症]

若任何一項病症答「有」，續問C19；否則跳至C20

C19 喺過去一個月內，你有冇因爲**[逐一讀出C18回答「有」嘅病症]**而接受過治療，包括定時或間中食藥？

	C18		C19	
病症	冇	有	冇	有
a. 高血壓	0 ☐	1 ☐	0 ☐	1 ☐
b. 心臟病或心血管問題	0 ☐	1 ☐	0 ☐	1 ☐
c. 糖尿病	0 ☐	1 ☐	0 ☐	1 ☐
d. 慢性頭痛或偏頭痛	0 ☐	1 ☐	0 ☐	1 ☐
e. 抑鬱或焦慮	0 ☐	1 ☐	0 ☐	1 ☐
f. 失眠症 (嚴重睡眠問題)	0 ☐	1 ☐	0 ☐	1 ☐
g. 消化性潰瘍(胃)	0 ☐	1 ☐	0 ☐	1 ☐
h. 哮喘	0 ☐	1 ☐	0 ☐	1 ☐

C20 喺過去一個月內，你有冇服用以下嘅藥物呢？ [讀出下列藥物]

若任何一種藥物答「有」，續問C21；否則跳至C22

C21 咁你有幾經常服用**[逐一讀出C20「有」服用嘅藥物]**呢？

	C20		C21					
藥物	冇	有	每日一次或多次	每星期兩次或以上但並非每日	每星期一次	每月兩次或以上但每星期少於一次	每月一次	每月少於一次
a. 降血壓藥	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
b. 心血管藥	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
c. 糖尿病藥	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
d. 安眠藥	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐
e. 鎮靜劑	0 ☐	1 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐

C22 喺冇配戴任何助聽器嘅情況下，你感覺聽嘢有冇任何問題或者困難？

冇 → **跳至C25**	0 ☐
有 → **C23**	1 ☐

若答「有」(C22=1)，續問C23；否則跳至C25

C23 請問你喺乜嘢情況下覺得聽覺有問題或困難呢？仲有呢？仲有冇呢？(記錄受訪者答案並按答案編碼表填下有關編碼)

______________________________ (   )

______________________________ (   )

______________________________ (   )

C24	你需唔需要配戴任何嘅助聽器呢？	
	唔需要	0 ☐
	需要	1 ☐

<u>讀出</u>：跟住係一啲關於你屋企同埋工作狀況嘅問題。

C25	你而家有冇全職或兼職工作呢？	
	有 - 全職 } **C26**	1 ☐
	- 兼職 } **C26**	2 ☐
	冇 → **C28**	3 ☐

若「有全職/兼職工作」(C25=1-2)，續問C26；否則跳至C28

C26	你份工有冇需要返通宵夜班/更工作呢？我指嘅通宵夜班/更係喺半夜12點至清晨6點內至少有4個鐘時間工作。	
	冇需要 → **跳至C28**	0 ☐
	有需要 → **C27**	1 ☐

若答「有需要」(C26=1)，續問C27；否則跳至C28

C27	咁，你係需要經常返通宵夜班/更，抑或係要輪日夜班/更呢？	
	經常返通宵夜班	1 ☐
	輪日夜班/更	2 ☐

C28	你喺呢個單位住咗幾多年呢？	
		[ ][ ] 年
	少於1年	999 ☐

C29	你哋呢一伙有幾多個..(讀出)..？	
	客廳／飯廳	[ ][ ] 個
	睡房／工人房	[ ][ ] 個
	書房／儲物房	[ ][ ] 個
	開放式單位	999 ☐

C30 一般喺平日，即星期一至五，你通常喺邊段時間會喺屋企呢？

1 ☐ 全日

	時		分			時		分	
2. 從上午 / 下午	[ ]	[ ]	[ ]	[ ]	到上午 / 下午	[ ]	[ ]	[ ]	[ ]
3. 從上午 / 下午	[ ]	[ ]	[ ]	[ ]	到上午 / 下午	[ ]	[ ]	[ ]	[ ]

C31	示咭 瞓覺時，你有幾經常會閂埋睡房嘅窗口呢？ (以全年計；若開放式單位，以整個單位計算)	
	從來都冇	1 ☐
	有時有	2 ☐
	好多時都有	3 ☐
	差唔多所有時間都有	4 ☐
	不適用 (冇窗口)	9 ☐

C32	示咭 喺日頭屋企有人嘅時候，佢哋喺屋企通常出入或者逗留嘅地方有幾經常會門埋啲窗呢？ (以全年計；若開放式單位，以整個單位計算)	
	從來都冇	1 ☐
	有時有	2 ☐
	好多時都有	3 ☐
	差唔多所有時間都有	4 ☐
	不適用 (冇窗口)	9 ☐

C33	你哋嘅客／飯廳有冇安裝冷氣機呢？ (若開放式單位，以整個單位計算)	
	冇	0 ☐
	有	1 ☐

C34	你哋嘅睡房有冇安裝冷氣機呢？ (若開放式單位，以整個單位計算)	
	冇	0 ☐
	有	1 ☐

C35	你有冇試過搵辦法減低住所外邊嘅噪音？	
	不適用 (冇噪音)	9 ☐
	冇	0 ☐
	有	1 ☐
	[如有，請註明方法]：____________________	

C36	呢一戶有冇睡房或瞓覺嘅地方冇對住馬路或鐵路呢？	
	冇	0 ☐
	有	1 ☐

C37	你可唔可以講出一啲嚟自屋企外面打擾、干擾或者煩擾你嘅噪音來源呢？仲有呢?仲有冇呢? (記錄受訪者答案並按答案編碼表填下有關編碼)
	1. ____________________ (　　)
	2. ____________________ (　　)
	3. ____________________ (　　)

F. 個人資料 (問所有家庭成員，10歲以下的家庭成員 (B2 <10) 由成人代答)

讀出: 爲 幫助我 分析資料，我想知道一 你 個人資料。你所提供 資料係會絕對保密。

F1 請問你而家 婚姻狀況係乜 呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
從未結婚..........	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
已婚..........	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
離婚 / 分居..........	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
喪偶..........	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
其他 (請註明)：	________	________	________	________	________	________

F2 請問你而家係唔係 學校或者教育機構讀緊書呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
係 → F3..........	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
唔係 → F5..........	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

若答「係」(F2=1)，續問F3；否則跳至F5。

F3 係全日制(包括小學嘅上/下午班)、部分時間制定係遙距課程呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
全日制 (包括小學上/下午班)..........	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
部分時間制 (兼讀)..........	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
遙距課程..........	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐

F4 你讀緊幾年級呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
幼稚園／幼兒園..........	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
小學 (小一至小三)..........	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
小學 (小四至小六)..........	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
初中 (F.1-F.3)..........	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
高中 (F.4-F.5)..........	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
預科 (F.6-F.7)..........	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
毅進計劃..........	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
工業學院／職業訓練學院 (學徒課程)...	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
工業學院／職業訓練學院 (證書課程)...	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
大專：(非學位課程／副學士學位課程).	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
大學：(學士學位課程)..........	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
大學：(碩士／博士學位課程)..........	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐

F5 你最高係讀到幾多年級或者乜 教育程度呢？ (請填寫最高完成程度)

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
未受教育完全不能閱讀..........	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
未受教育能閱讀少許生字..........	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
幼稚園／幼兒園..........	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
小學 (小一至小三)..........	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
小學 (小四至小六)..........	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
初中 (F.1-F.3)..........	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
高中 (F.4-F.5)..........	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
預科 (F.6-F.7)..........	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
毅進計劃..........	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
工業學院／職業訓練學院 (學徒課程)...	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
工業學院／職業訓練學院 (證書課程)...	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
大專：(非學位課程／副學士學位課程).	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
大學：(學士學位課程)..........	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
大學：(碩士／博士學位課程)..........	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐

F6 請問你係唔係持單程證由內地來港呢？
若「係」，追問：請問你喺香港居住滿七年未呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
係						
- 滿七年	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
- 未滿七年	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
唔係	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐

若15歲或以上人士，續問 F7；否則跳至F14

F7 請問你喺過去七日有冇全職或者兼職工作呢？包括自己做生意又或者幫屋企嘅生意工作而冇收人工都計，包括任何做咗一個鐘頭或者以上嘅工作。

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
有 → F8	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
冇 → F10	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

若答有（F7=1），續問 F8；否則跳至F10

F8 你喺邊個行業工作呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
農業、漁業、採礦及採石	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
製造	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
電力、燃氣和自來水供應及廢棄物管理	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
建造	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
進出口貿易及批發	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
零售	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
住宿及膳食服務	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
運輸、倉庫、郵政及速遞服務	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
資訊及通訊	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
金融及保險	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
地產	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
專業及商用服務	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
公共行政	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
社會及個人服務	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐
其他（請註明）：	______	______	______	______	______	______

F9 咁你係做乜嘢職位呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
經理及行政級人員	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
專業人員	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
輔助專業人員	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
文員	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
服務工作及商店銷售人員	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
漁農業熟練工人	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
工藝及有關人員	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
機台及機器操作員/裝配員	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
非技術工人	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
其他（請註明）：	______	______	______	______	______	______

跳至F14

F10 咁喺過去七日內，如果有人請你做工，你可唔可以隨時返工呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
可以 → F12	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
唔可以 → F11	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

若答唔可以（F10=2），續問F11；否則跳至F12

F11　係乜嘢原因你唔可以隨時返工呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
返學 ... F14	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
料理家務 ... F14	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
已退休 ... F14	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
生病 (長期) ... F14	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
生病 (非長期) → F12	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
其他（請註明）：	______	______	______	______	______	______

若答非長期生病（F11=5），續問F12；否則跳至F14

F12　喺過去30 日內，你有冇搵工做呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
有 → F14	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
冇 → F13	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐

如答冇（F12=2），續問F13；否則跳至F14

F13　點解你冇搵工呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
相信冇工作可做	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
等候返新工	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
期待返回原有工作崗位	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
稍後自己開業	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
其他（請註明）：	______	______	______	______	______	______

F14　示咭
請問你而家有以下邊　收入來源呢？仲有呢？仲有呢？ （可複選）[MA]

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
工作收入/薪金	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
花紅	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
房屋津貼	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
退休金/長俸	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
綜緩	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
傷殘津貼	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
老人津貼/生果金	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
利息/股息	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
非同住親友　經濟支持	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
租金收入	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
助學金 (貸款除外)	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
其他 (請註明)：	______	______	______	______	______	______
冇收入	97	97	97	97	97	97

若有任何收入來源 **(F14≠97)**，續問**F15**；否則，戶主跳至**F16**；其他家庭成員，跳至**F16**之後。

F15 <u>示咭</u>
包括所有收入來源同埋強積金供款，請問你每月 <u>個人</u>收入大約有幾多錢呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
$1 - $999	20 ☐	20 ☐	20 ☐	20 ☐	20 ☐	20 ☐
$1,000 – $1,999	19 ☐	19 ☐	19 ☐	19 ☐	19 ☐	19 ☐
$2,000 – $2,999	18 ☐	18 ☐	18 ☐	18 ☐	18 ☐	18 ☐
$3,000 – $3,999	17 ☐	17 ☐	17 ☐	17 ☐	17 ☐	17 ☐
$4,000 – $4,999	16 ☐	16 ☐	16 ☐	16 ☐	16 ☐	16 ☐
$5,000 – $5,999	15 ☐	15 ☐	15 ☐	15 ☐	15 ☐	15 ☐
$6,000 – $6,999	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐	14 ☐
$7,000 – $7,999	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐	13 ☐
$8,000 – $8,999	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐	12 ☐
$9,000 – $9,999	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐	11 ☐
$10,000 – $12,499	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐	10 ☐
$12,500 – $14,999	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐	9 ☐
$15,000 – $19,999	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐	8 ☐
$20,000 – $24,999	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐	7 ☐
$25,000 – $29,999	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
$30,000 – $39,999	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
$40,000 – $49,999	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
$50,000 – $59,999	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
$60,000 – $69,999	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
$70,000 或以上	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐

F16 <u>只問 “戶主”</u>
<u>示咭</u>
包括所有收入來源同埋強積金供款，請問你 <u>(屋企/呢伙人)</u> 每月嘅家庭總收入大約有幾多錢呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
$1 - $999	20 ☐					
$1,000 - $1,999	19 ☐					
$2,000 – $2,999	18 ☐					
$3,000 - $3,999	17 ☐					
$4,000 – $4,999	16 ☐					
$5,000 – $5,999	15 ☐					
$6,000 – $6,999	14 ☐					
$7,000 – $7,999	13 ☐					
$8,000 – $8,999	12 ☐					
$9,000 – $9,999	11 ☐					
$10,000 – $12,499	10 ☐					
$12,500 – $14,999	9 ☐					
$15,000 – $19,999	8 ☐					
$20,000 – $24,999	7 ☐					
$25,000 – $29,999	6 ☐					
$30,000 – $39,999	5 ☐					
$40,000 – $49,999	4 ☐					
$50,000 – $59,999	3 ☐					
$60,000 – $69,999	2 ☐					
$70,000 或以上	1 ☐					
冇收入（請註明原因）	97 ☐					

- 多謝受訪者，並讀出 -
爲咗保証我哋嘅訪問質素，我哋公司嘅品質保證部門(QA)有機會喺稍後嘅時間再聯絡閣下作簡短嘅抽樣覆查，以確保數據嘅準確，希望閣下能夠再次合作。

另外，為咗幫助我哋將來計劃進行呢類統計調查及改進我哋ｅ 服務，我哋想知道你對有關呢項統計調查ｅ 數據搜集方法ｅ 意見。你ｅ 意見對我哋檢討調查ｅ 運作有好大幫助。

F17 示咭
下一次進行呢項統計調查ｅ 時候，假設貴住戶獲抽選中，你最想選擇以下邊一種方法交回呢份調查問卷呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
(a) 網上提交	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
(b) 回郵寄出...	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
(c) 上門面訪	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
(d) 其他方法（請註明）:	______	______	______	______	______	______

F18 示咭
下一次進行呢項統計調查ｅ 時候，假設貴住戶獲抽選中，而你只需提供有關住宅單位同埋家庭成員ｅ 年齡同埋性別ｅ 資料，你最想選擇以下邊一種方法交回呢份調查問卷呢？

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
(a) 網上提交	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
(b) 回郵寄出...	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
(c) 上門面訪	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
(d) 其他方法（請註明）:	______	______	______	______	______	______

F19 (記錄訪問形式)

	a	b	c	d	e	f
	成員(戶主)	成員2	成員3	成員4	成員5	成員6
上門訪問						
- 受訪者本人作答..................................	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐	1 ☐
- 他人代答(只適用於受訪者少於10歲、年紀太大或智力問題未能親自作答)	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐	2 ☐
[記錄代答者編號]................................	______	______	______	______	______	______
- E部份由他人代答(只適用於受訪者少於16歲、年紀太大或智力問題未能親自作答)	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐	3 ☐
[記錄代答者編號]................................	______	______	______	______	______	______
電話訪問						
- 受訪者本人作答..................................	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐	4 ☐
- 他人代答(只適用於受訪者少於10歲、年紀太大或智力問題未能親自作答)	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐	5 ☐
[記錄代答者編號]................................	______	______	______	______	______	______
- E部份由他人代答(只適用於受訪者少於16歲、年紀太大或智力問題未能親自作答)	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐	6 ☐
[記錄代答者編號]................................	______	______	______	______	______	______

- 全卷完，多謝受訪者，並讀出 -
再次多謝閣下嘅寶貴意見。再見！

A1.

C1.

好唔滿意

唔滿意

冇乜話滿唔滿意

滿意

好滿意

C4.

完全唔煩擾										極之煩擾
0	1	2	3	4	5	6	7	8	9	10

C5/C6.

從來都冇

有時有

好多時有

差唔多所有時間都有

C7.

完全唔煩擾										極之煩擾
0	1	2	3	4	5	6	7	8	9	10

C8.

完全唔干擾										極之干擾
0	1	2	3	4	5	6	7	8	9	10

C12.

十分唔同意					十分同意
0	1	2	3	4	5

C13.

完全唔煩擾

有啲煩擾

煩擾

好煩擾

極之煩擾

C14.

非常好

好

普通

唔好

非常差

C15.

比一年前好得多

比一年前好啲

同一年前差唔多

比一年前差啲

比一年前差得多

C31/C32.

從來都冇

有時有

好多時有

差唔多所有時間都有

F14.

工作收入/薪金 1

花紅..2

房屋津貼..3

退休金/長俸 4

綜緩..5

傷殘津貼..6

老人津貼/生果金 7

利息/股息 8

非同住親友經濟支持..9

租金收入..10

助學金 (貸款除外)..11

其他 (請註明)：______________________________

F15/F16.

$1 - $999 20

$1,000 – $1,999.. 19

$2,000 – $2,999.. 18

$3,000 – $3,999.. 17

$4,000 – $4,999.. 16

$5,000 – $5,999.. 15

$6,000 – $6,999.. 14

$7,000 – $7,999.. 13

$8,000 – $8,999.. 12

$9,000 – $9,999.. 11

$10,000 – $12,499.. 10

$12,500 – $14,999.. 9

$15,000 – $19,999.. 8

$20,000 – $24,999.. 7

$25,000 – $29,999.. 6

$30,000 – $39,999.. 5

$40,000 – $49,999.. 4

$50,000 – $59,999.. 3

$60,000 – $69,999.. 2

$70,000 或以上**... 1**

F17/F18.

網上提交**..1**

回郵寄出**..2**

上門面訪**..3**

其他方法 **(**請註明**)**：______________________________

WORKING PAPER

ON

A REVIEW OF ANNOYANCE EFFECTS WITH TRANSPORTATION NOISE

FOR

THE PROVISION OF SERVICE FOR THE STUDY OF HEALTH EFFECTS OF TRANSPORTATION NOISE IN HONG KONG

ENVIRONMENTAL PROTECTION DEPARTMENT, HKSAR GOVERNMENT

TENDER REF. AN 08-047

Prepared by Professor Lex Brown of Griffith University

April 2011

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1. Introduction

Annoyance is one non-auditory *health endpoint* (or *health outcome*) of interest related to human exposure to environmental noise. Van Kempen et al. (2005) examined a range of *recent* overviews regarding the effects of environmental noise (HCN, 1994), (Porter et al., 1998), (HCN, 1999), (Van Kempen et al., 2002), (Staatsen et al., 2004) (Van Kamp et al., 2004) identifying the following set of health outcomes that are reported in relation to noise exposure:

- Direct masking effects (e.g. speech interference);
- Behavioural responses such as coping strategies;
- 'Social' responses such as annoyance or perceived sleep disturbance;
- Acute physiological responses (endocrine and neurophysiological reactions, such as transient blood pressure increases and sleep stage changes);
- Cognitive responses such as task interference, effects on children's learning;
- Chronic physiological responses e.g. hypertension.

In a more recent review, Berry and Flindell (2009) identified similar non-auditory heath effects:

- Annoyance;
- Mental health effects;
- Cardiovascular and physiological effects;
- Night time effects, sleep disturbance;
- Cognitive effects of noise on children.

This paper focuses on the first of these non-auditory health effects – human annoyance with noise from all transportation sources, with particular emphasis on annoyance resulting from surface transport sources of road traffic and railways.

The Working Paper is based on reviews of the most recent literature relevant to this annoyance endpoint. While it is a comprehensive review of relevant literature from the last decade, for clarity and parsimony, wherever possible, it cites and builds on previous recent reviews, syntheses, and related consensus documents that exist in this field, rather than re-examining the original research projects and results on which the reviews and syntheses were based. In selecting material for this review, the Working Paper has included matters that may prove relevant to future understanding of the relationship between exposure to noise and community response to noise in the Hong Kong population, and to policy-making and management of surface transportation noise in Hong Kong. It has been cognisant of the review and plot study in Hong Kong reported in Wong (2002).

Gjestland (2008) notes that there has been few large-scale research projects on community response to noise (annoyance) during the last five years – though there are recent large studies around airports at Schiphol and Frankfurt. The last decade has, however, been characterised by significant re-analysis and meta-analysis of existing survey data.

Other Working Papers prepared in this current project review the literatures of sleep disturbance and of cardiovascular effects of noise.

2. The interpretation of annoyance

2.1 Noise annoyance

Wong (2002) provided the following interpretation of annoyance:

> *The term "annoyance", a core concept in the research of environmental effects with considerably varied meaning among experts, is generally seen as a negative evaluation of environmental conditions (Guski, et al., 1999). The concept embraces disturbance, aggravation, concern, bother, displeasure, harassment, irritation, nuisance, vexation, exasperation, discomfort, uneasiness, distress and hate. Annoyance has been defined as "a feeling of displeasure associated with any agent or condition, known or believed by an individual or a group to adversely affect them (Berglund, et al., 1999)".*

In a similar vein, Passchier-Vermeer and Passchier (2000), in a comprehensive review of noise exposure and public health for the Dutch Health Council, note that "*Noise annoyance is a feeling of resentment, displeasure, discomfort, dissatisfaction, or offense when noise interferes with someone's thoughts, feelings, or actual activities*". They report annoyance as a long-term health-effect of noise, and that there is sufficient evidence of a causal relationship between annoyance and outdoor environmental noise exposure.

It is now widely accepted that annoyance is an endpoint of environmental noise that can be taken as a basis for evaluating the noise-impact on exposed populations. For example, the Environmental Noise Directive (END) in Europe (Council Directive 2002/49/EC, 2002) recommends evaluating environmental noise exposures on the basis of estimated noise annoyance, in addition to evaluation on the basis of estimated sleep disturbance. Passchier-Vermeer and Passchier (2000) note that: "*While it is not yet possible to predict noise annoyance on an individual basis because of the large variety of (partly unknown) endogeneous and exogeneous characteristics that affect annoyance, the relationships between noise annoyance and noise exposure have been elucidated on a population level together with several effect-modifying factors*".

Public health experts generally agree that high levels of noise-related annoyance should be considered as a legitimate environmental health issue affecting the wellbeing and quality of life of the population exposed to environmental noise (Health Protection Agency, 2009), though Berry and Flindell (2009) leave open the question of whether it is, in itself, a health effect, or part of complex process by which noise can be a stressor and lead to more adverse effects.

2.2 The stress model of effects of noise

More severe health effects of noise may be mediated through annoyance, as high levels of noise-induced annoyance is shown to be associated with increased risk of morbidity (Niemann and Maschke, 2004). Babisch *et al*. (2003) report evidence that noise annoyance due to exposure to road traffic may be a risk factor for the incidence of ischaemic heart disease, with pre-existing chronic diseases modifying this association.

Babisch's hypothesised noise effects reaction model is shown in Figure 1. Apart from the direct pathway of high levels of noise exposure resulting in hearing loss, the indirect pathway is through disturbance of activities, sleep and communication. Annoyance can be seen as the cognitive and emotional response to these disturbances – and to this extent it can be seen as a health endpoint. However, the model suggests that this is a contributor to human stress, with stress providing the causal link to other heath endpoints. Thus, according to this model, noise annoyance by itself is an adverse outcome of exposure to noise as well as a contributor to those further effects (or an indicator that further effects may occur). However there is limited evidence, and no consensus, that increased annoyance response is an intermediary in the noise exposure/physiological response pathway.

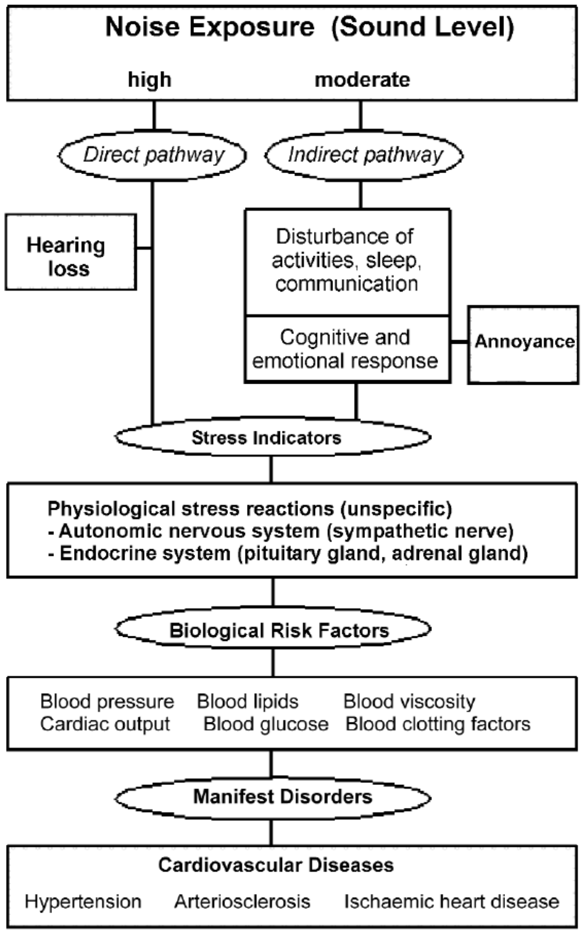

Figure 1: Noise effects reaction schema (Source: Babisch, 2002)

Lercher (1996) illustrates various major conceptual models that are effectively utilised in non-auditory health effects of noise research: a general-stress model, an individual situational difference model, and a transactional model.

Further understanding of the notion of annoyance is suggested in the conceptual model of Stallen (1999) which is rooted in the psychological stress theory of Lazarus (1966). Psychological aspects which have been studied extensively include: people's perception of their degree of control of the situation, and strategies people chose to reduce the negative impacts of their environmental stressors (coping). Coping may include actively trying to solve the problem, attempts at avoidance by adopting "life style" factors (smoking, alcohol, drugs, medication use) or cognitive strategies.

Active coping is generally considered as the most effective strategy that people can adopt, and avoidance as the least effective (van Kamp, 1990). However in contrast to personal problems, environmental exposures are often outside the control of people and even though active coping leads to reduced stress feelings, and annoyance, it can, in the long term, lead to increased risk of hypertension (van Kamp, 1990). This is a consequence of the environmental factor lying outside the control of the individual, which in itself can enhance stress and lead to long-term health problems.

This model of coping and stress, as simplified and adapted by Kroesen *et al*. (2009) is shown in Figure 2. The model postulates that perceived disturbance is a person's evaluation of the threat, or harm in relation to well-being, and the acoustic exposure is the main determinant of this evaluation. After a threat or harm is recognised, a secondary appraisal is triggered, and the resources to face the threat are evaluated, viz through non-acoustic factors and perceived control and coping capacity. Stress, or annoyance, is the potential outcome after those two appraisals if the threat is larger than the resources to manage that threat. To incorporate the reciprocal relationships between disturbance and annoyance, and perceived control and coping and annoyance, Kroesen *et al*. extended the model as in Figure 3.

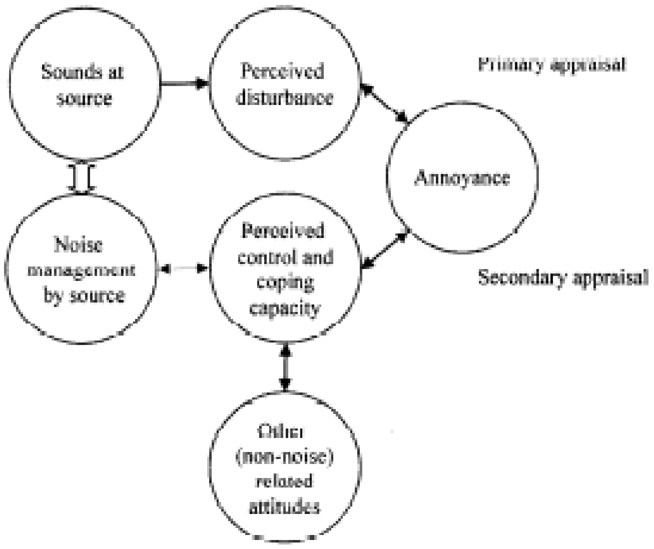

Figure 2: The conceptual model of Stallen (1999) used to explain noise annoyance. Noise annoyance is defined as a form of psychological stress which is determined by the perceived impact of a stressor and the perceived resources to cope with this stressor (Source: Kroesen et al., 2009)

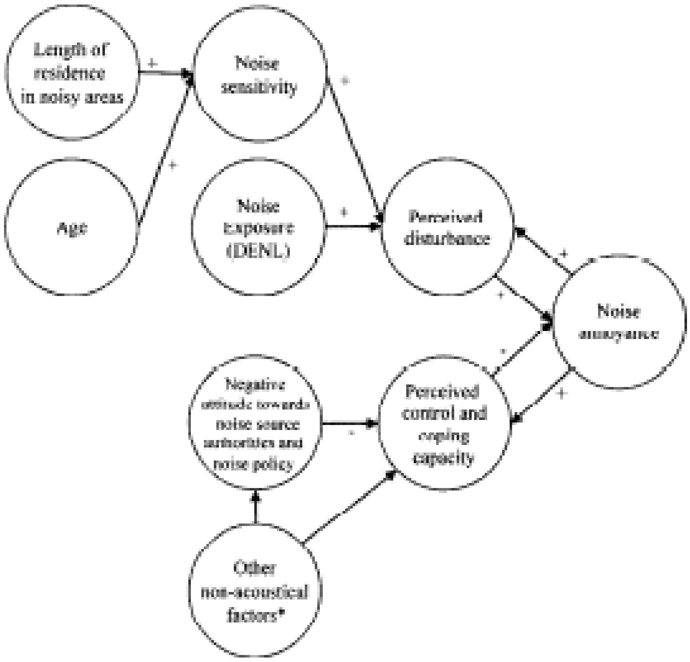

Figure 3: The developed causal model of annoyance (Source: Kroesen et al., 2009)

They then went on to validate the model using Structural Equation Modelling using empirical data from Amsterdam Airport Schiphol. It shows reciprocal relationships between perceived disturbance and annoyance, and perceived control and coping capacity and annoyance, supporting earlier evidence of the role of control and coping (van Kamp, 1990).

3. Measurement of annoyance

Noise annoyance is usually assessed by means of a questionnaire. The wording of questions in a social survey is critical as differences in survey questions wordings and weakness in some questions used to measure noise annoyance have interfered with accumulating knowledge about the factors that affect different communities' responses to noise (Fields *et al.*, 2001).

Efforts have been made by the International Commission on Biological Effects of Noise (ICBEN) and the International Organization of Standardization (ISO TS 15666, 2003) towards the use of standardized questions asking for the degree of annoyance. ICBEN set the goal of creating high-quality survey questions that would yield internationally comparable measures of overall reactions to noise sources. After seven years of discussions and research, a method was developed and tested, yielding a pair of multi-purpose questions for community noise surveys. The standardized general-purpose noise reaction questions were translated into ten different languages: Dutch (Flemish), English, French, German, Hungarian, Japanese, Norwegian, Polish, Spanish, and Turkish. A standardized procedure for establishing the modifiers for a verbal annoyance scale and to translate the standardized questions into other languages has also been developed (Gjestland, 2008). This work has been extended now to Chinese (Mandarin), Korean and Vietnamese (Yano and Ma, 2004).

The standardised questions (in English) are:

- *Thinking about the last 12 months or so, when you are here at home, what number from 0 to 10 best shows how much you are bothered, disturbed, or annoyed by the following* [source of noise]?, with a numerical response scale ranging from 0 (not at all) to 10 (extremely).
- *Thinking about the last 12 months or so, when you are here at home, how much does noise from* [source of noise] *bother, disturb, or annoy you*?, with a semantic response scale of: not at all; slightly; moderately; very; extremely.

These questions and scales, and their application, are described in full in an International Organization of Standardization standard *Acoustics -- Assessment of noise annoyance by means of social and socio-acoustic surveys* (ISO/TS 15666: 2003).

Annoyance measured in this way is presumed to be some longer-term integration of respondents' experiences and disturbances over a year, and while the standardised questionnaire attempts to minimise differences through standardisation, if and how this integration takes place is unknown (Guski, 1999).

Further guidance on the reporting of information on community noise reaction surveys is provided in Fields *et al*. (1997).

The numerical response scale can be converted into a 0-100 annoyance response scale, and cut-off values of 50 and 72 have been used to determine the percentage of people *annoyed* (%A) and *highly annoyed* (%HA), respectively. The percentage highly annoyed, i.e. the percentage of persons with a response exceeding 72, is the most widely used indicator of the prevalence of annoyance in a population, although percentages using other cut-offs or the mean annoyance may also be used (cf. Miedema and Oudshoorn, 2001).

It is essential to note, and to explain to both decision-makers and the public, that irrespective of whether the measure of community response is %HA, %A, or a mean value of annoyance, there is always wide variation in individual responses to any particular level of exposure. This should be borne in mind when utilizing the exposure-response curves discussed in Section 5.0 below. There is nothing unusual, or untoward, in a wide range of human responses to any environmental factor, including environmental noise.

4. Noise metrics for assessment of annoyance

4.1 Noise metrics

The noise metrics (or noise indicators, or noise scales) adopted to assess and manage transportation noise immission – that is, noise immission primarily to dwellings—varies considerably from country to country.

Based on an I-INCE international survey, Tachibana and Lang (2005) reported the following:

> ***Road Traffic Noise****: Virtually all surveyed countries have…national road traffic immission policies. The road traffic immission noise policies are typically embodied in guidelines, although some countries have now adopted immission regulations for road traffic noise…There is more variability in the metrics used to control road traffic noise than for other transportation noise sources. Although the majority of countries use a time-based LEQ metric, such as an LEQ for the busiest hour of the day, it is also not uncommon to see road traffic noise metrics such as L10.*
>
> ***Aircraft Noise****: Most countries…have noise immission guidelines concerning aircraft noise intrusion into overflown communities…noise immission national guidelines reflect economic and technical considerations relevant to the circumstances of each country, the same as for road traffic noise. For aircraft noise immission policies, the most common noise metric is LEQ(24) or some variant of this, such as the Day-Night Average Sound Level (DNL), or perhaps Day-Evening-Night Average Sound Level (DENL). The use of WECPNL seems to be declining around the world, although many countries have still been using their own aircraft noise metrics, such as NNI, NEF, and Kosten units. However, in the future, all European Union countries will be required to use the Day-Evening-Night Average Sound Level (DENL), as described in the new European Commission Environmental Noise Directive, although they will also be allowed to also maintain their own separate noise indices/metrics if they choose.*
>
> ***Railway Noise****: Most countries have a…community noise intrusion guidelines. Again, the guidelines allow flexibility for local conditions, but most countries use LEQ or one of its variants.*

In summary: All of the noise metrics in use for surface transport are A-weighted levels. They are based on statistical centile values (e.g. $L_{10,T}$ the level exceed for 10% of the specified period T), or energy equivalent continuous sound level ($L_{eq,T}$). The period T has been as short as 1 hour (often the peak hour) or most or all of the day (e.g. $L_{eq,24h}$). In the USA initially, and now elsewhere, the energy equivalent continuous sound level for the twenty-four hour period has been time weighted, with a penalty of 10 dB for night time noise (22.00-7.00 hrs) to allow for the fact that community response can be heightened during the night hours (L_{dn}, or DNL: the Day-Night Average Sound Level). This has been extended, initially in Europe, by including a 5 dB penalty to noise in the evening (L_{den}, or DENL: the Day-Evening-Night Level). The various noise metrics for air transport noise include the energy equivalent continuous sound levels and the time-weighted variations of these, but also metrics which combine levels of noise with the number of "noise events".

All these noise metrics are utilised on the basis that they relate to annoyance, disturbance or some related human reaction to noise. Many can be traced back to an original investigation, or synthesis of studies, that has attempted to obtain the best "predictor" of community annoyance for a particular transport noise source, and many of these have been cross-sectional exposure-response studies (see Section 5.0 below) that have sought the noise metric with a reasonable correlation with community annoyance.

However the adoption and continued use of the different noise metrics depends as much on the inertia of regulations, standards and current practice as it does on current scientific evidence. For example, several places continue to use $L_{10,18h}$ for road traffic noise, though the origins for that choice is a study in the UK over 30 years ago (Langdon, 1976). Different studies in different countries have lead to the evolution of this plethora of noise metrics.

In making a choice of any particular noise metric there are two matters that should be considered. Firstly, the metric should correlate with annoyance within the population of interest (or the metric should correlate with annoyance in a synthesis of studies from elsewhere). Secondly, provided the first condition is met, there are benefits in harmonising the noise metric with other countries in terms of being able to compare population exposures and limit values, and to utilise prediction models and other tools that are developed elsewhere.

The European Union has adopted specific noise metrics on this basis across all member countries. While noise limits are set by EU Member States, the harmonised noise metrics are L_{den}, to assess annoyance, and L_{night}, to assess sleep disturbance. These metrics are common across all transport sources, and other sources of environmental noise. A definition of these metrics in the END (Council Directive, 2002) is shown in the Box below—paraphrased to focus on matters relevant to transport noise. The END also allows the use of supplementary metrics to monitor or control special noise situations

The day-evening-night level L_{den} in decibels is defined by:

$$L_{den} = 10\lg\frac{1}{24}\left(12*10^{\frac{L_{day}}{10}} + 4*10^{\frac{L_{evening}+5}{10}} + 8*10^{\frac{L_{night}+10}{10}}\right)$$

• L_{day} $L_{evening}$ and L_{night} are the A-weighted long-term average sound level as defined in ISO 1996-2: 1987;

• the day is 12 hours, the evening four hours and the night eight hours. The Member States may shorten the evening period by one or two hours and lengthen the day and/or the night period accordingly (same for all the sources)

• the start of the day (and consequently the start of the evening and the start of the night) shall be chosen by the Member State (same for all sources); the default values are 07.00 to 19.00, 19.00 to 23.00 and 23.00 to 07.00 local time,

• the incident sound is considered, which means that no account is taken of the sound that is reflected at the façade of the dwelling under consideration

The night-time noise indicator L_{night} is the A-weighted long-term average sound level;

• the night is eight hours as defined above

Supplementary noise indicators: In some cases, in addition to L_{den} and L_{night}, and where appropriate L_{day} and $L_{evening}$, it may be advantageous to use special noise indicators and related limit values. Some examples are given below:

• the average number of noise events in one or more of the periods is very low (for example, less than one noise event an hour; a noise event could be defined as a noise that lasts less than five minutes; examples are the noise from a passing train or a passing aircraft),

• the low-frequency content of the noise is strong,

• L_{Amax}, or SEL (sound exposure level) for night period protection in the case of noise peaks.

The END has resulted in a considerable increase of activity in Europe with respect to strategic noise mapping for estimating the extent of exposure to environmental noise and to the development of action plans to manage noise issues.

4.2 Noise events

Gjestland (2008) notes that it is an often forgotten fact that one "does not hear an equivalent level". In a community noise setting, the noise is perceived as a series of more or less distinct events. He suggests that the equivalent level is not necessarily telling the full story with respect to human response, and that different traffic noise situations with the same L_{eq}, may be assessed differently with respect to annoyance. Wong (2002) reviewed a range of studies in which noise events were examined with respect to annoyance:

> *Research by Bjorkman et al. (1992 [049]) indicated that annoyance reaction was better related to the number of noise events ≥ 70dBA and the maximum noise level compared to the energy equivalent level for noise exposure. A dose-response relationship between annoyance and the number of noise events ≥ 70dBA was observed in the study by Rylander et al. (1997). In most other studies (Yoshida et al., 1997], Kurra, et al., 1999), the energy equivalent level was found to be an important predictor of annoyance. Sato, et al. (1999) found that the 24 h LAeq but not the number of noise events was related to annoyance.*

Methods currently used to measure, manage and regulate road traffic noise (vis-à-vis measurement, management and regulation of noise emitted by individual vehicles) are based on what can be called the continuous scales/descriptors of exposure to road traffic noise. Noise descriptors, such as the Leq, provide a single number that represents the equivalent amount of non-fluctuating sound over the same measurement period, are relatively simple to measure, and exposure-response relationships between these continuous measures and human health effects presume that community response is a monotonically increasing function of the continuous measures. However, these traditionally accepted noise descriptors say very little about the pattern of noise over time. There is emerging consensus about the importance of noise events in the pattern of noise over time in explaining human reaction to noise. Sleep disturbance caused by road traffic noise is a major component of the community noise health issue (Health Council of the Netherlands, 1994; Berglund *et al*., 1999; EnHealth Council, 2004) and the research evidence is that it is the maxima of noise in the traffic stream that is the primary determinant of sleep disturbance.

Noise maxima also affect human performance, speech interference and annoyance. For example, for annoyance, Roberts et al. (2003) note that various studies demonstrate anomalies to the accepted view that it is the continuous measures that are important, postulating that it is the pattern of road traffic noise – the presence of noise peak events (such as those of trucks) that may be critical. They suggest that response to road traffic noise may be better assessed by some combination of the conventional continuous noise measures and pattern variables (e.g. maxima/ number of noise events).

The significance of noise events vis-à-vis the continuous noise measures has often been noted:

- While this index (L10) has found widespread use amongst road authorities around the world there is criticism that it does not accommodate the occurrence of single noisy vehicles adequately (Wooley et al., 1988).
- These averaging measures obscure the very real differences in the variation over time of different types of noise. Noise environments which are very different when compared in terms of descriptors of the actual noisy events can in fact be nominally equivalent in terms of 24-hour average levels. (Hall et al., 1985).

Hall et al. (1985) and Taylor et al. (1987) examined an activity interference model of noise effects, and concluded that their results justified further research on an events-based model. Guski (1999) also concludes, “It seems that the residents do not respond to (energy measurements of noise) but instead to noisy events, i.e. to the amount, distribution, duration, levels and the meaning of acoustic emissions.” De Meur et al. (2005) also presented a model grounded in the hypothesis that noise effects are primarily determined by noticed intruding sounds.

Despite these observations and the growing evidence of the dependence of human response to noise peaks in the traffic streams, event-based research into human response to transport noise remains limited. The issue of noise events in the traffic stream as a determinant of annoyance is still unresolved.

5. Exposure-response relationships for annoyance

In the past 30 years, many (largely cross-sectional) studies have established exposure-response relationships for annoyance from transport noise. The first real attempt to establish a general dose-response function for annoyance with transport noise was Schultz (1978), followed by Fidell et al. (1991) and Finegold et al. (1994). They presented synthesized curves for all such surveys for which noise exposure (as L_{dn}) and the percentage of highly annoyed persons were available.

Schultz (1978) used data of 11 studies (161 data points) from the UK, France, Germany, Sweden, Switzerland and the USA, published between 1961 and 1972, pooling results from road, rail and air traffic noise. In 1991, Fidell et al. presented an update of the Schultz-curve, adding 15 new studies and deleting others, resulting in analysis of 27 studies (453 data points). Least squares analysis was used to develop both curves, resulting in a third order polynomial and a quadratic curve respectively. Finegold et al. (1994) reanalysed this data set, again using a least squares analysis, but excluding 6 studies (400 data points). The three curves are shown in Figure 4.

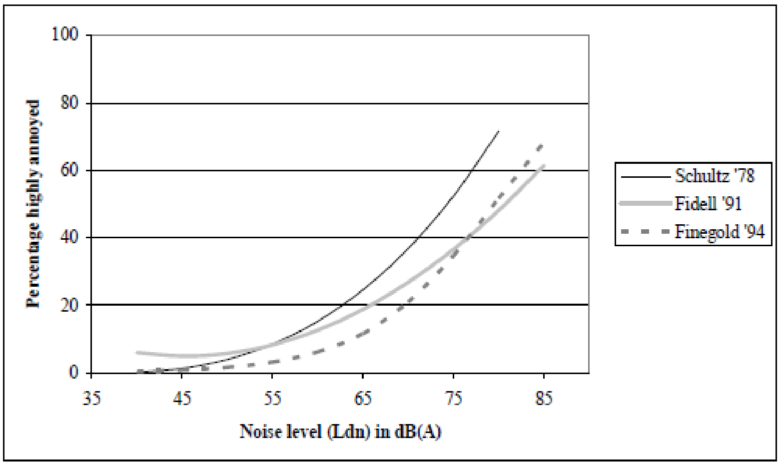

Figure 4: Exposure-effect-relationships for the relation between noise exposure Ldn and annoyance (Source: Schultz, 1978; Fidell et al., 1991; Finegold et al., 1994)

Miedema and Vos (1998) more recently provided synthesized curves separately for aircraft, road traffic and railway noise, adding the results of some newer studies to the data used by Schultz, Fidell and Finegold. A later reanalysis of much of this data also established confidence limits on the estimate of human response to transport noise exposure (Miedema and Oudshoorn, 2001). Miedema and Vos (1998) made use of the data of 20 aircraft surveys published between 1965 and 1992 from different European countries, Australia, USA and Canada; of 26 road traffic studies (period 1971-1994 from different European countries and Canada); and of 9 railway studies (period 1972 to 1993 from France, Germany, the Netherlands, Sweden and the UK), and used both ordinary least squares regression and a multilevel procedure. The results were published using both L_{dn} and L_{den}. They also included results, not only for the percentage highly annoyed (%HA), but for the percentage annoyed (%A) and the percentage a little annoyed (%LA). The results for the %HA and the L_{den} metric are shown in Figure 5. Those for the %A and the L_{den} metric, including 95% confidence interval (dotted lines) are shown in Figure 6.

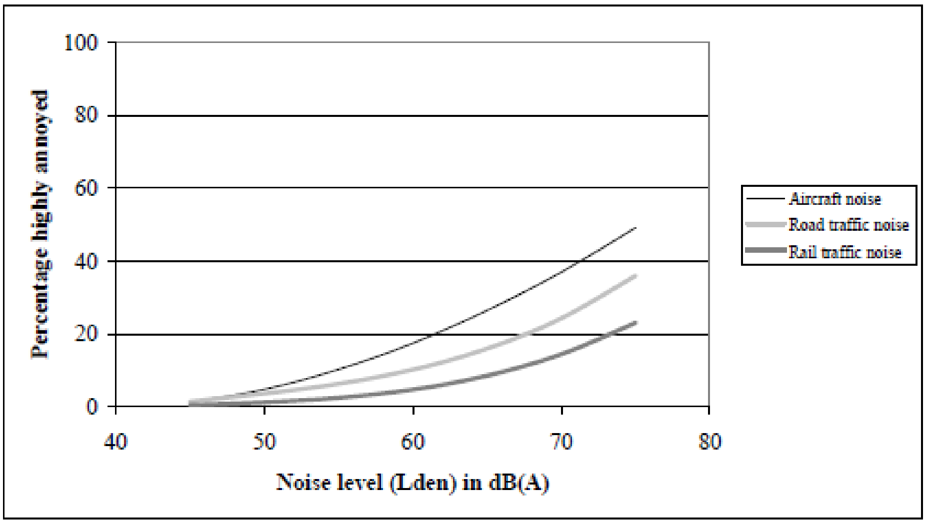

Figure 5: Exposure-effect-relationships for the association between noise (expressed as Lden) from different sources and annoyance (Source: Miedema and Oudshoorn, 2001)

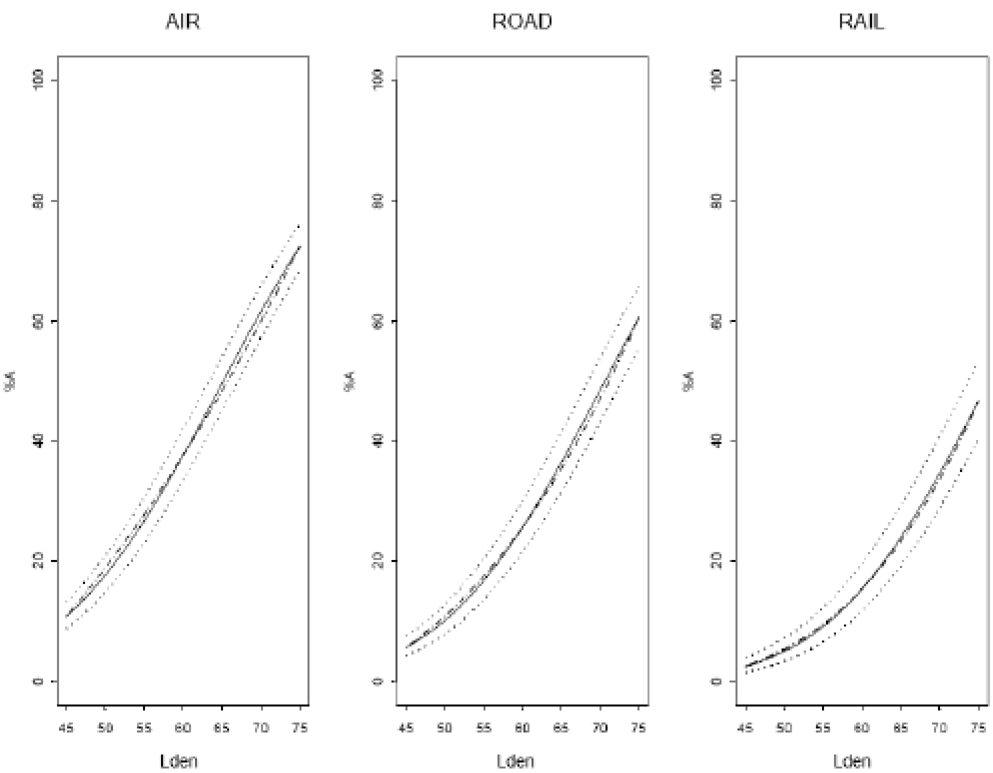

Figure 6: The percentage annoyed persons (%A) as a function of the noise exposure of the dwelling (L_{den}) (Source: European Communities, 2002)

The EC working group on health effects of environmental noise recommended (European Communities, 2002) the relationships presented by Miedema and Oudshoorn (2001) for estimating noise annoyance based on the external noise exposure of dwellings. Approximate relationships are shown in the table below.

Measure/source	DNL	DENL
%LA		
Aircraft	$-5.741 \times 10^{-4}(DNL-32)^3 + 2.863 \times 10^{-2}(DNL-32)^2 + 1.912(DNL-32)$	$-6.158 \times 10^{-4}(DENL-32)^3 + 3.410 \times 10^{-2}(DENL-32)^2 + 1.738(DENL-32)$
Road traffic	$-6.188 \times 10^{-4}(DNL-32)^3 + 5.379 \times 10^{-2}(DNL-32)^2 + 0.723(DNL-32)$	$-6.235 \times 10^{-4}(DENL-32)^3 + 5.509 \times 10^{-2}(DENL-32)^2 + 0.6693(DENL-32)$
Railways	$-3.343 \times 10^{-4}(DNL-32)^3 + 4.918 \times 10^{-2}(DNL-32)^2 + 0.175(DNL-32)$	$-3.229 \times 10^{-4}(DENL-32)^3 + 4.871 \times 10^{-2}(DENL-32)^2 + 0.1673(DENL-32)$
%A		
Aircraft	$1.460 \times 10^{-5}(DNL-37)^3 + 1.511 \times 10^{-2}(DNL-37)^2 + 1.346(DNL-37)$	$8.588 \times 10^{-6}(DENL-37)^3 + 1.777 \times 10^{-2}(DENL-37)^2 + 1.221(DENL-37)$
Road traffic	$1.732 \times 10^{-4}(DNL-37)^3 + 2.079 \times 10^{-2}(DNL-37)^2 + 0.566(DNL-37)$	$1.795 \times 10^{-4}(DENL-37)^3 + 2.110 \times 10^{-2}(DENL-37)^2 + 0.5353(DENL-37)$
Railways	$4.552 \times 10^{-4}(DNL-37)^3 + 9.400 \times 10^{-3}(DNL-37)^2 + 0.212(DNL-37)$	$4.538 \times 10^{-4}(DENL-37)^3 + 9.482 \times 10^{-3}(DENL-37)^2 + 0.2129(DENL-37)$
%HA		
Aircraft	$-1.395 \times 10^{-4}(DNL-42)^3 + 4.081 \times 10^{-2}(DNL-42)^2 + 0.342(DNL-42)$	$-9.199 \times 10^{-5}(DENL-42)^3 + 3.932 \times 10^{-2}(DENL-42)^2 + 0.2939(DENL-42)$
Road traffic	$9.994 \times 10^{-4}(DNL-42)^3 - 1.523 \times 10^{-2}(DNL-42)^2 + 0.538(DNL-42)$	$9.868 \times 10^{-4}(DENL-42)^3 - 1.436 \times 10^{-2}(DENL-42)^2 + 0.5118(DENL-42)$
Railways	$7.158 \times 10^{-4}(DNL-42)^3 - 7.774 \times 10^{-3}(DNL-42)^2 + 0.163(DNL-42)$	$7.239 \times 10^{-4}(DENL-42)^3 - 7.851 \times 10^{-3}(DENL-42)^2 + 0.1695(DENL-42)$

While these relationships are recommended in Europe, there is, effectively, an "Atlantic divide" in terms of standardised exposure response curves for annoyance from transport noise. Gjestland (2008), in a recent review, provides the following commentary on these differences (using L_{dn} as the common noise metric):

> *Miedema and Oudshoorn (2001) performed a re-analysis of 47 different surveys on transportation noise. Their results, which were later "adopted" by the EU for noise assessment according to the Directive 2002/49/EC (2002), are shown in Figure 7.*

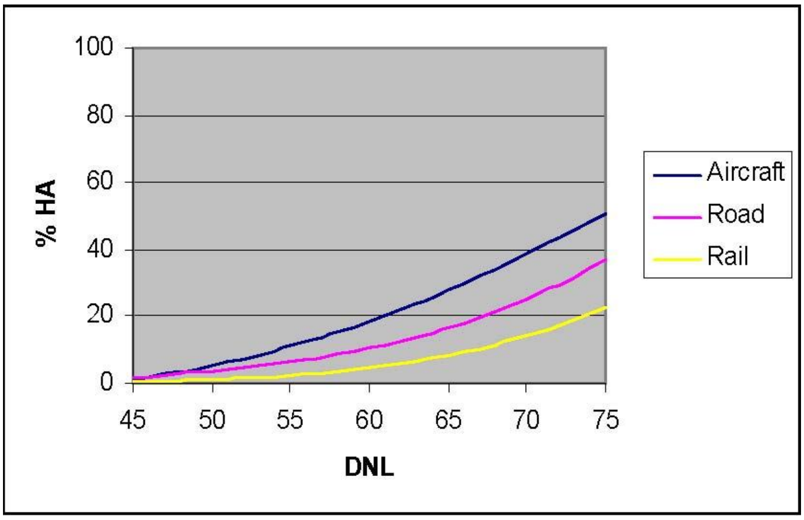

Figure 7: Dose-response functions for transportation noise: percentage highly annoyed versus LDN (Source: Miedema & Oudshoorn, 2001)

> *The dose-response functions for aircraft, road, and rail are distinctly different, and separated by approximately 6 dB. This corresponds to a 6 dB "rail bonus" and a 6 dB "aircraft malus" compared to road traffic noise. These differences are not constant, as the three dose-response functions are different (and not only shifted sideways).*
>
> *The revised international standard ISO 1996 – Part 1 (2003) suggests another dose-response function. This is the "original" Schultz curve. The standard has a table for source dependent corrections. Aircraft noise levels are corrected "3 to 6 dB" relative to road traffic noise and the railroad bonus is also defined as "3 to 6 dB".*

Figure 8 shows a comparison of the Miedema and Oudshoorn (2001) function for road traffic noise (adopted by EU) and the corresponding function suggested by ISO. The difference between the two is greatest around Ldn 60 dB, about 3 dB. The difference for railroad and aircraft can be much greater depending on the choice of correction factor.

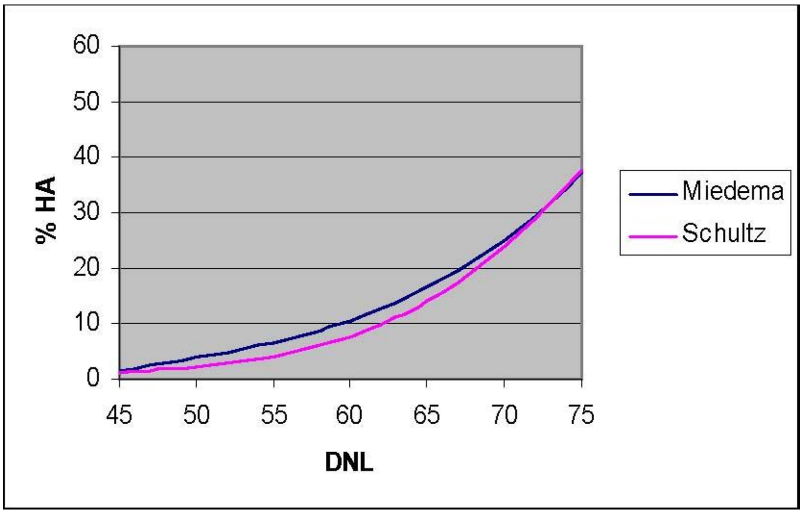

Figure 8: Dose-response functions for road traffic noise used by EU (Source: Miedema & Oudshoorn 2001) and ISO 1996 (Source: Schultz 1978)

The American standard ANSI 12.9 – Part 4 (2003) specifies yet another dose-response function. This standard uses the same function as ISO 1996, but the correction factors are different. There is no railroad bonus, and the aircraft noise penalty varies between "0 dB" and "5 dB".

In other words, three recognized parties use three different dose-response functions for assessing the annoyance from transportation (and other types of) noise. And these dose-response functions are based on more or less the same set of data.

The issue of railroad bonus is quite controversial. ISO 1996 specifies that the bonus should not be applied to trains at higher speed than 250 km/h. The Miedema and Oudshoorn (2001) curves have a railroad bonus of about 6 dB, and no restrictions on train speed.

These relationships represent averages over large populations that were chronically exposed to noise at specified levels for periods of more than a year. They do not necessarily apply to situations in which there has been a change in exposure (see Section 6.0 below). Further, it should be emphasised that all these "accepted" relationships are syntheses of many individual studies, and van Kempen et al. (2005) warn that the generalizability of such derived exposure-effect curves to different countries and different areas has not been well established:

What makes it complicated is that not only personal but also situational problems play a role: it is not unlikely that there are substantial differences in terms of susceptibility to noise. It is hypothesized that the annoyance responses of people in different countries deviate from the established curves because of differences in cultural expectations about the acceptability of transportation noise exposure, differences in climate and the adequacy of housing sound insulation techniques (Staatsen et al., 2004)...Much depends on the extent to which a variety of inherent *and acquired personal factors interact with environmental factors (HCN, 2004)… Other factors that may produce bias in terms of transferability to other populations are differences in daily pattern of activity, climatic conditions, housing, and different importance of confounding factors that might not have been properly controlled for in the epidemiological studies. But also differences in flight patterns and the composition of the aircraft- and road traffic fleet between the countries can be of importance (Van Kempen et al., 2003).*

Estimating response of a local population from the generalised curves:
Especially on a local level, a prediction of the fraction of people highly annoyed based on an estimate of exposure may differ considerably from the outcome of a specific survey of annoyance in an exposed population (Passchier-Vermeer and Passchier, 2005).

Cultural bias in the generalised curves:
Most exposure-response studies included in the synthesised curves are from Europe, North America and Australia, and there have been few studies from Asia, or from areas with high residential densities, high road traffic densities, or different urban forms, such exist in Hong Kong, or that have gone through rapid periods of economic growth and urbanisation.

However, there have been several recent surveys on annoyance reactions to transportation noise that have been conducted in Japan. Yano et al. (2007) have studied the response to road traffic, rail and aircraft noise in Japan (Figure 9). Their results seem to confirm the Miedema and Vos (1998) relationship for road traffic noise, but they report a much higher annoyance due to aircraft noise. Their results also show that noises from railroads are more annoying than noise from road traffic, in contrast to what is usually found in Europe, perhaps due to different types of trains.

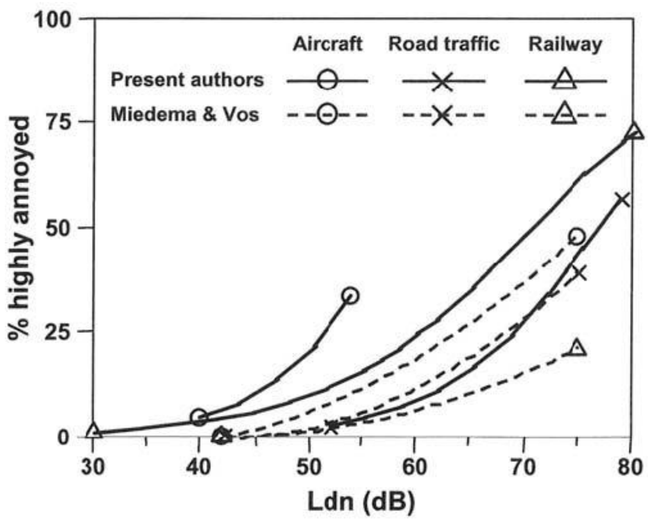

Figure 9: Dose-response functions reported by Yano et al. (2007) compared with function reported by Miedema and Vos (1998)

Ota et al. (2007) (Figure 10) found that the response to conventional railroad noise and road traffic noise is quite similar, whereas noise from high speed trains, the Shinkansen, cause reactions similar to aircraft noise. There is no indication of a so-called “railroad bonus” in Japan.

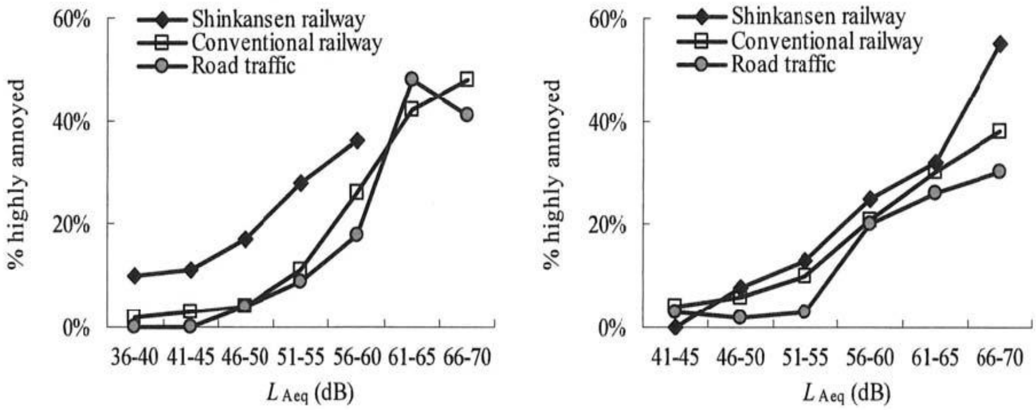

Figure 10: Dose-response functions of residents living in detached houses (left) and apartment buildings (right) (Source: Ota et al., 2007)

The only exposure-response curve from other countries in Asia has been reported by Phan et al. (2007) who have studied the response to road traffic noise in Vietnam (Figure 11). The results cover a restricted, but higher, range of traffic noise exposures, but over the common range, are not dissimilar to those reported by Miedema and Vos (1998).

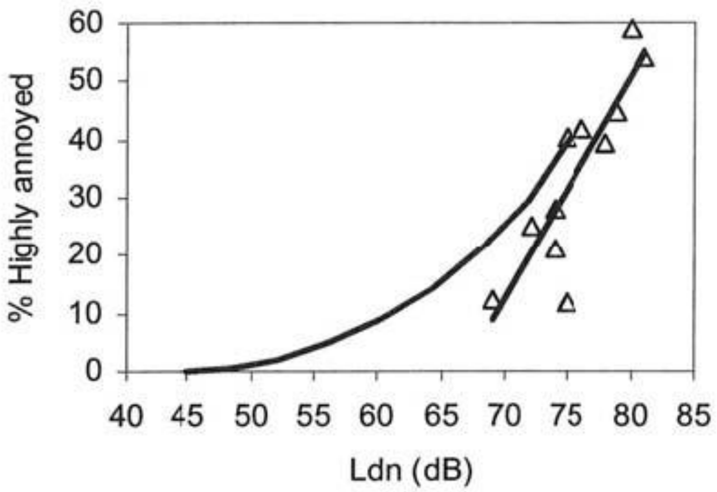

Figure 11: Dose-response functions reported by Phan et al. (2007, straight line) compared with function reported by Miedema and Vos (1998, curved line)

5.1 Changes in exposure-response curves over time?

It can be noted that much of the data on which the generalised curves have been based are several decades old and therefore may not represent current conditions. While there is nothing inherently wrong with combining data from different decades, it does overlook the possibility that societies may be changing in terms of their response (that is, their acceptance or intolerance) to any particular exposure. Such changes could occur as a result of community learning, or changing community values. The Health Protection Agency (2009) suggests that there is accumulating evidence that attitudes and opinions to noise may have been changing significantly over the past twenty or thirty years. That report noted that residents around English airports were more annoyed at the same levels of exposure (L_{Aeq}) than were those in 1982, suggesting that exposure-response relationships for noise may not have been stable over time. There are also issues in this with respect to changing relationships between the level of individual aircraft noise events (reducing over time) and the number of aircraft overflights (increasing over time). If residents are reacting more to the increase in the number of overflights, they could be reporting more annoyance for any given L_{Aeq}. Berry and Flindell (2009) noted that a discrepancy of higher annoyance at any given level of exposure had also been found in a study around Schiphol airport.

This issue is flagged as one of current concern and debate, but not one on which there is agreement as to the explanation.

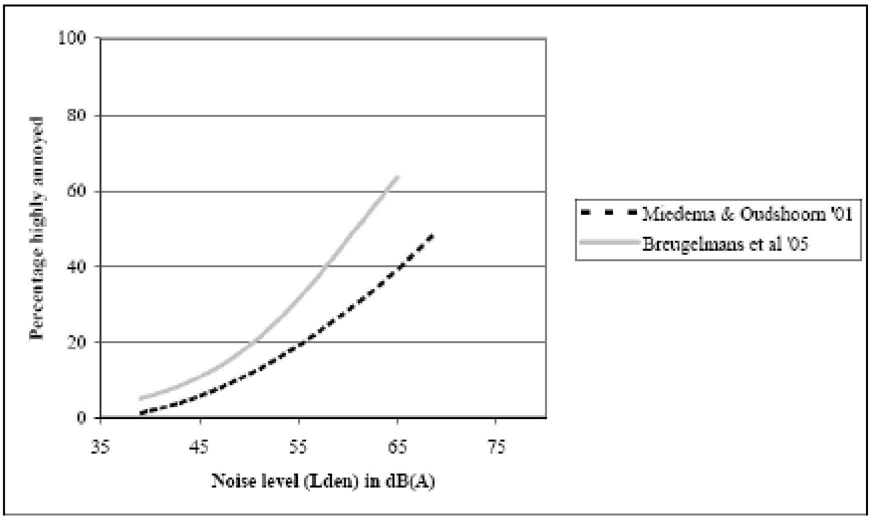

Figure 12: Comparison between a recent exposure-response curve of annoyance derived by Breugelmans et al. (2005) with aircraft noise compared to the much lower levels of annoyance estimated by the Miedema and Oudshoorn (2001) synthesised curves (Source: Berry and Flindell, 2009)

6. Response to change in noise exposure

Most studies on community reaction to noise, including those from which exposure-response relationships have been derived, have been conducted where the noise situation has been stable for a considerable period of time. However, step changes in transport noise exposure occur in range of practical situations:

- New roads and railways are constructed or existing ones closed;
- There are major increases or decreases in road, rail or air traffic;
- Noise mitigation measures are implemented in high noise environments;
- New airport runways are constructed, or existing ones closed;
- There is a major changes in the mix of road vehicle types, trucks in particular; and
- Where there is a major re-arrangements of flight paths.

These are always significant changes as far as the community and authorities are concerned, and a prediction of the response of the community to that change is an important part of assessment of the proposed changes.

The literature suggests that such situations of change can result in a excess-response change-effect in the reaction of people that live in the surroundings of the noise source: respondents whose noise exposure has increased as a consequence of a change in their noise situation report more annoyance than can be expected on the base of the generalized exposure-response relation; or respondents whose noise exposure has decreased as a consequence of a change in their noise situation report less annoyance than that can be expected on the base of the generalized exposure-response relation. Brown and Van Kamp (2009a), in reviewing evidence of a change-effect, have demonstrated that it is unequivocally present in the results of road traffic noise studies where the intensity of the road traffic source changes through changes in traffic volume on the source roadways. This effect is present even for quite small changes in noise exposure. For these types of change situations, the decibel-equivalent magnitude of the excess responses (both the excess benefit arising from reductions in exposure, and the excess disbenefits arising from increases in exposure) can be greater, often much greater, than the change in noise levels itself. For changes resulting from the insertion of barriers or other path mitigation interventions changes), the evidence for a change effect is not clear. The excess-response change effect does not appear to attenuate over time - even years after the change

The studies on which Brown & Van Kamp (2009a) based their review were heterogeneous in terms of metrics and designs and since the approximations necessary to estimate the change-effect from the data reported in these studies differed, it was not possible to derive a relation between the change in noise exposure and the change effect. However that the magnitude of the change effect (in dB equivalent: the additional number of decibels of change in exposure that would be required to obtain the measured human response – moving along the exposure-response curve) was often greater than the change in the noise exposure itself, is shown in Figure 13).

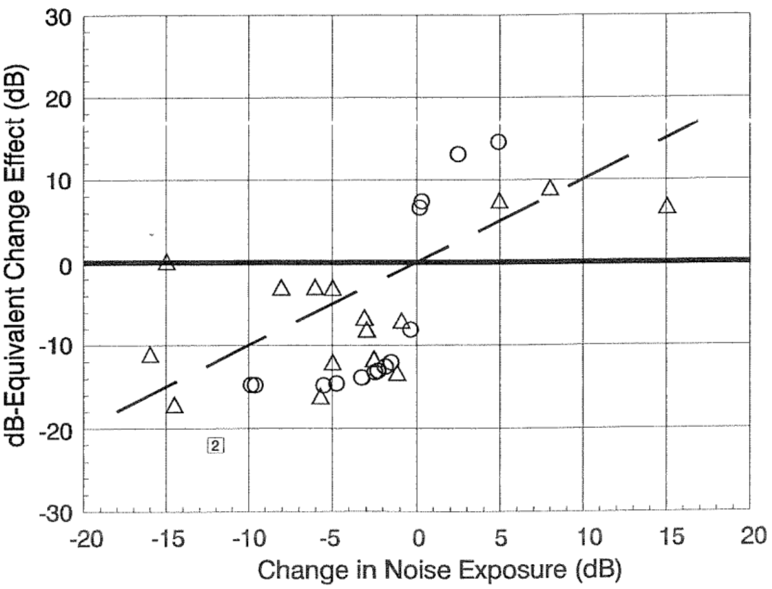

Figure 13: Decibel-equivalent excess response change-effect for studies investigating situations where the change in noise exposure has resulted from changes in the roadway source itself, the construction of new roadways, either as new sources or providing traffic relief on existing roadways, or some other change in traffic flow. The broken line indicates a change-effect of the same magnitude (dB-equivalent) as the change in noise exposure (Source: Brown & van Kamp, 2009a)

Brown and van Kamp (2009b) examined the wide range of explanations that have been postulated for a change effect. While several of the explanations can be discarded, the residual plausible explanations are of three categories: changes in modifiers of exposure-response relationships in the context of change in exposure; differential scaling criterion for the annoyance scale at different levels of exposure; and retention of coping strategies following a change.

There are significant policy implications of the change effect in terms of assessing human response in situations of change, irrespective of mechanism, and several of the mechanisms raise important questions regarding interpretation of the exposure-response relationships based on steady-state surveys.

7. Non-acoustical factors influencing annoyance with noise

The annoyance literature shows that noise exposure explains about 25-30% of the observed variance in annoyance. There have been extensive reviews of the other factors that are known to influence annoyance.

Guski (1999) differentiates between moderator variables and mediator variables as shown in Figure 14. Moderating variables are independent of the stimulus, but co-vary with the reaction. Mediating variables depend on the stimulus variable, but also influence the reaction.

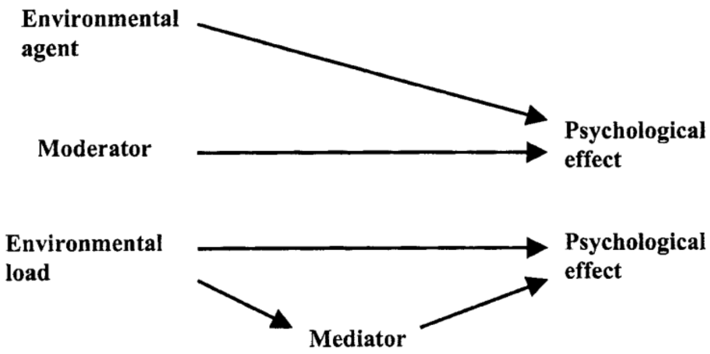

Figure 14: The structure of relations between environmental agent (in this case noise), moderator and mediator variables, and psychological reaction (in this case annoyance) (Source: Guski, 1999)

Moderator and mediator variables include personal and social factors. Personal factors are variables characteristic of an individual that vary from one individual to the next, but with considerable stability over time (e.g. sex and socio-economic status). Social factors are linked to situations (e.g. expectations regarding noise abatement).

In a major review of the effect of personal and situational variables on annoyance, Fields (1993) summarised:

> *… annoyance is not affected to an important extent by…the amount of time residents are at home, the type of interviewing method or any of nine demographic variables (age, sex, social status, income, education, home ownership, type of dwelling, length of residence, or receipts of benefits from the source). Annoyance is related to the amount of isolation from sound at home and to five attitudes (fear of danger from the noise source, noise prevention beliefs, general noise sensitivity, beliefs about the importance of the noise source, and annoyance with non-noise impacts of the noise source)."*

To a large extent, these findings have not been altered by subsequent work. Guski (1999) identifies four personal moderators:

- Sensitivity (or susceptibility) to noise;
- Fear with respect to the source;
- Attitude to source;
- Capacity to cope with noise.

and four social factor moderators:

- General evaluation of the noise sources (including perceived economic advantage);
- Trust or misfeasance of authorities;
- History of noise exposure;
- Residents' expectations.

These non-acoustical factors play a major role in annoyance responses, with these personal and social factors explaining about one-third of the observed variance in response. Of these, anxiety (fear of the noise source) and noise sensitivity are the most important non-acoustical factors of influence in exposure-response relationships (Fields, 1993; Guski, 1999; Job, 1999, Stallen, 1999; van Kamp et al., 2004). In commenting on the correlation of noise sensitivity to the noise annoyance reaction, Job (1999) notes evidence that it is not that noise exposure is shaping both noise sensitivity and annoyance (hence sensitivity is not a mediator variable), but the direction of causality between sensitivity and annoyance is difficult to establish.

Regarding the measurement of Noise Sensitivity, Weinstein (1978) developed one of the first noise sensitivity scales and there has subsequently been a range of versions of this scale in use, together with scales such as NoiSeQ (see, for example Schutte et al., 2007). More recently, Kishikawa et al. (2006) suggested a shorter version of the Weinstein scale, successfully testing it in Japan. A useful review of noise sensitivity scales can be found in Heinonen-Guzejev (2009) and Zimmer and Ellermeier (1999).

8. Estimating the proportion of the Hong Kong population "highly annoyed" with road traffic noise

For adults, the relation for the association between road traffic noise (outdoor level, most exposed façade, L_{den}) and several degrees of annoyance (% a little annoyed, % annoyed, and % highly annoyed) derived by Miedema and Oudshoorn (2001) is at the moment the best available (See Section 5.0 above). Because, to those authors, there was no practical need for information concerning the annoyance at very low and very high levels (defined as L_{den} < 45 dB(A) or L_{den} >75 dB(A)), these levels were excluded from their analyses.

It would be possible to use this relationship to make preliminary estimates of the likely number of adults in Hong Kong who are "highly annoyed" with road traffic noise (equally, estimates could be made of the numbers "annoyed' or "a little annoyed"). This would requires two assumptions: firstly, that that the current estimates of the exposure of the Hong Kong population to road traffic noise, available as $L_{10,\ 1h}$ at the facades of dwellings (Lee et al., 2006) can be approximately converted to exposures in terms of L_{den} (using conversion Lden= L10- 0.9dB(A) in Lee et al. (2003), and secondly that the exposure-response relationship synthesised by Miedema and Oudshoorn (2001) can reasonably be applied to the Hong Kong (adult) population.

9. Calculating Environmental Burden of Disease (EBD) of transportation noise

Gestland (2008) notes that:

> *Community noise is often ignored by politicians and decision makers because it cannot "compete" with other pollutants. The fact that people "are annoyed" is often regarded not so serious that one needs to take any action.*
> *Good health, as defined by the World Health Organization (WHO), implies a "state of complete physical, mental, and social well being". Annoying noises are therefore per definition unhealthy. WHO is now including noise annoyance in their document "Burden of disease". Annoyance will be rated along with other negative health factors, and will be given a specific "weight" that can be assessed in the same way as other "ordinary" diseases.*

There are currently increasing attempts to estimate the effect of environmental burden of disease caused by environmental, particularly transport, noise. This is done through a Health Impact Assessment process. Van Kempen (2009) describes the process in Figure 15 below.

Stassen et al. (2008) provide an example of the calculation of the environmental burden of disease due to exposure to environmental noise from transport, including cardiovascular diseases, sleep disturbance and annoyance, in Flanders, Belgium. The burden of disease due to transportation noise was quantified based on the disability adjusted life year methodology (DALY), combining the burden due to premature death and disability in a single index. The estimated number of DALYs due to transportation noise in Flanders in 2004 was 20,517, corresponding to 1.7% of the burden of disease in Flanders or 21.8% of the environmental burden of disease due to particular matter, ozone, carcinogenic air pollutants and noise. However, they noted that their results must be interpreted carefully because of the rather large uncertainty range attributable to the variety in exposure level, the uncertainty of exposure–response functions and the choice of the severity weight. The WHO will be publishing a methodological guidance, later in 2010, for estimation of EBD for road traffic noise.

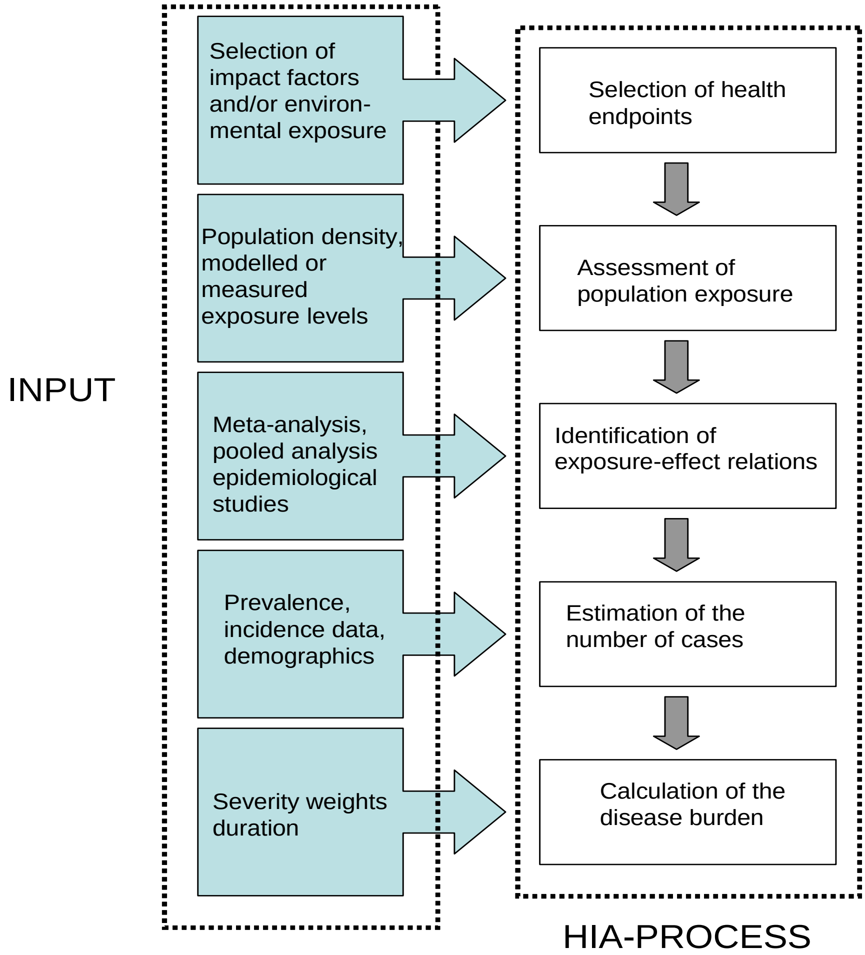

Figure 15: Calculation of the Environmental Burden of Disease of transport noise (Source: van Kempen, 2009)

10. Noise and children

Studies on community response to noise are often limited to a “normal adult population”. Groups with special needs, and groups that are particularly vulnerable to noise can be easily overlooked, and children seem to be at risk.

Van Kempen et al. (2005) notes the following:

> *While annoyance is one of the most frequently studied noise effects in adults, children’s annoyance with noise sources appears to be an under researched area. Until now, only a few studies looked at it: the Munich Airport study (Evans et al., 1995) (Evans et al., 1998) (Hygge et al., 2002), the Heathrow studies (Haines et al., 2001a) (Haines et al., 2001b) (Haines et al., 2001c), the Tyrol study (Lercher et al., 2000) (Lercher et al., 2002) and the RANCH-study (Van Kamp et al., 2003) (Stansfeld et al., 2005). In these studies children were consistently found to be annoyed by chronic noise exposure. Most studies focus on aircraft noise. A recent study (Haines et al., 2003) found indications that child noise annoyance is the same construct as adult noise annoyance: the emotional response of children to describing the annoyance reaction was consistent with adult reactions. Some see it as an affective response that points to a chronic decline in well being. For both parents and teachers steeper, exposure-response curves were observed than for children (Van Kamp et al., 2003) (Lercher, 2002). Recently, Boman and Enmarker found that teachers were more annoyed than their pupils. It appeared that the teachers perceived the noise to be more unpredictable than the pupils (Boman and Enmarker, 2004).*

The most recent evidence, van Kempen et al. (2009), shows that, although children report annoyance, they score lower at the higher end of annoyance scales and thus seem to be less vulnerable as far as annoyance is concerned.

11. Soundscapes and annoyance

A new dimension has been added to noise research through the introduction of the soundscape concept. The emerging field of soundscape studies has some relevance to this Working Paper on Annoyance. As Brown (2007) notes:

> *Significant realignment towards soundscapes has been forced by the EU Environmental Noise Directive, part of which has lead to the notion of identifying "quiet areas" - or more appropriately "areas of high acoustic quality" (Brown, 2006) - and attempts to define and map these. Researchers in environmental and community noise are also beginning to investigate the contribution that soundscape philosophies and approaches can make to an understanding of human response to sound, in both urban and non-urban contexts, and its potential role in environmental noise management. This includes the role of source and context in human experience of noise (Raimbault, (2006), notions of the restorative capacities of soundscapes on human health and well-being and the value of high quality acoustic environments to people otherwise living in noisy urban environments (Kilman, 2002; Gidlöf-Gunnarsson and Öhrström, 2007; Öhrström et al., 2006).*

New studies indicate, for instance, that people who have access to a quiet side of their house, a quiet back yard or even a quiet nearby park or recreational area, are less annoyed by noise than people without access to such areas. The Swedish research program "Soundscape Support to Health" has previously shown that the "quiet side concept" is a factor of significance for moderating the adverse health effects of road traffic noise (Öhrström et al., 2006). It has also shown that good availability to nearby green areas furthermore can enhance the positive effects of access to a quiet side, but also that nearby green areas has an important role by itself for moderating the adverse effects of traffic-noise Gidlöf-Gunnarsson and Öhrström (2007). Their conceptual model of this effect is shown in Figure 16.

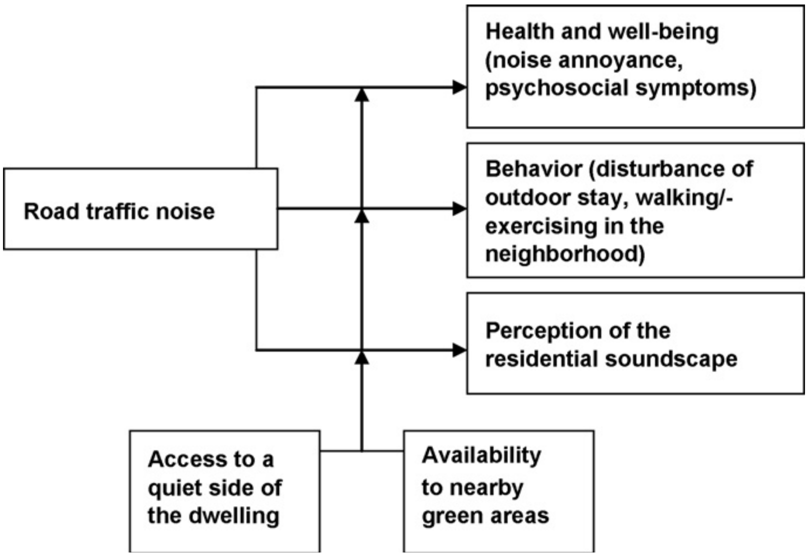

Figure 16: A conceptual model of the role of soundscapes in annoyance studies (Source: Gidlöf-Gunnarsson and Öhrström, 2007)

While noise annoyance from road traffic is predicted from noise exposure is most often calculated at the most exposed side of the dwelling or apartment. It has been demonstrated

(Klæboe et al., 2005) that, for people living in apartments facing side streets and backyards or in second row dwellings that are shielded from a main road by intervening building structures, an adverse neighbourhood soundscape has a substantial impact on residential noise annoyance. Results show that exposure–effect relationships ignoring neighbourhood soundscape information are misleading. In particular, annoyance reductions due to shielding apartments are likely to be overestimated, while the impacts of noise reduction at the source are likely to be underestimated.

A focus on soundscapes is a statement that the whole of people's acoustic experience is important and warrants management – not just the low quality, noisy, end of the outdoor acoustic environment. It encourages consideration of the urban (and non-urban) acoustic environment as a resource, not just as a waste to be managed. It also encourages adoption of the concept of acoustic design (Kang, 2007; Brown and Muhar, 2004).

12. Conclusions

1) Annoyance is one non-auditory health endpoint (or health outcome) of interest related to human exposure to environmental noise.
2) Noise annoyance is a feeling of resentment, displeasure, discomfort, dissatisfaction, or offense when noise interferes with someone's thoughts, feelings, or actual activities.
3) Public health experts agree (though not universally) that high levels of noise-related annoyance should be considered a legitimate environmental health issue affecting the wellbeing and quality of life of the population exposed to environmental noise (Health Protection Agency, 2009),
4) Environmental Noise Directive (END) in Europe (Council Directive 2002/49/EC, 2002) recommends evaluating environmental noise exposures on the basis of estimated noise annoyance, in addition to evaluation on the basis of estimated sleep disturbance.
5) While it is not yet possible to predict noise annoyance on an individual basis because of the large variety of (partly unknown) endogeneous and exogeneous characteristics that affect annoyance, the relationships between noise annoyance and noise exposure have been elucidated on a population level together with several effect-modifying factors.
6) Babisch et al. (2003) report evidence that noise annoyance due to exposure to road traffic may be a risk factor for the incidence of ischaemic heart disease, with pre-existing chronic diseases modifying this association, though there is no consensus on this as yet.
7) Under a stress model of the effects of noise, noise annoyance by itself is an adverse outcome of exposure to noise as well as a contributor to those further effects (or an indicator that further effects may occur). However there is limited evidence, and no consensus, that increased annoyance response is an intermediary in the noise exposure/physiological response pathway.
8) People may reduce the negative impacts of their environmental stressors (noise) by coping strategies.
9) Active coping is generally considered as the most effective strategy that people can adopt, and avoidance the least effective (van Kamp, 1990). However, environmental exposures are often outside the control of people and even though active coping leads to reduced stress feelings, and annoyance, it can, in the long term, lead to increased risk of hypertension (van Kamp et al., 1990). This is a consequence of the environmental factor lying outside the control of the individual, which in itself can enhance stress and lead to long-term health problems.
10) Standardised procedures (ISO/TS 15666: 2003) are available for questionnaire assessment of annoyance, and these should be used in all Hong Kong studies of annoyance.
11) The noise metrics (or noise indicators, or noise scales) adopted to assess and manage transportation noise immission – that is, noise immission primarily to dwellings – still varies considerably from country to country.
12) However the adoption and continued use of the different noise metrics depends as much on the inertia of regulations, standards and current practice as it does on current scientific evidence.
13) In making a choice of any particular noise metric there are two matters that should be considered. Firstly, the metric should correlate with annoyance within the population of interest (or the metric should correlate with annoyance in a synthesis of studies from elsewhere). Secondly, provided the first condition is met, there are benefits in

harmonising the noise metric with other countries in terms of being able to compare population exposures and limit values, and to utilise prediction models and other tools that are developed elsewhere.

14) The European Union has adopted specific noise metrics on this basis across all member countries. While noise limits are set by EU Member States, the harmonised noise metrics are L_{den}, to assess annoyance, and L_{night}, to assess sleep disturbance. These metrics are common across all transport sources, and other sources of environmental noise.
15) The issue of noise events in the traffic stream as a determinant of annoyance is still unresolved.
16) Extensive meta analyses have lead to the production of several different exposure-response relationships between annoyance and transportation noise exposure.
17) The EC working group on health effects of environmental noise recommended (European Communities, 2002) the relationships presented by Miedema and Oudshoorn (2001) for estimating noise annoyance based on the external noise exposure of dwellings – with different curves for aircraft, train and road traffic.
18) However, other exposure-response curves for annoyance from transport noise:
    - The revised international standard ISO 1996 – Part 1 (2003). The standard has a table for source dependent corrections. Aircraft noise levels are corrected as “3 to 6 dB” relative to road traffic noise and the railroad bonus is also defined as “3 to 6 dB”.
    - The American standard ANSI 12.9 – Part 4 (2003) specifies yet another dose-response function. This standard uses the same function as ISO 1996, but the correction factors are different. There is no railroad bonus, and the aircraft noise penalty varies between “0 dB” and “5 dB”.
19) The generalizability of such derived exposure-effect curves to different countries and different areas has not been well established. Issues that are relevant for Hong Kong (and elsewhere) are that:
    - Prediction of the fraction of people highly annoyed based on an estimate of exposure may differ considerably from the outcome of a specific survey of annoyance in an exposed population (Passchier-Vermeer and Passchier, 2005).
    - Most exposure-response studies included in the synthesised curves are from Europe, North America and Australia, and there have been few studies from Asia, or from areas with high residential densities, high road traffic densities, or different urban forms, such exist in Hong Kong, or that have gone through rapid periods of economic growth and urbanisation.
    - There is debate over the appropriateness of a “railway bonus” – response in Japan to road traffic and conventional rail traffic was the same.
    - The generalised curves have been based on data several decades old and therefore may not represent current conditions. The UK Health Protection Agency (2009) suggests that there is accumulating evidence that attitudes and opinions to noise may have been changing significantly over the past twenty or thirty years (increasing annoyance at the same exposure). This is an issue of current concern and debate, but not one on which there is agreement as to the explanation.
20) Step changes in transport noise exposure occur in range of practical situations such as where new roads and railways are constructed or existing ones closed or there are major increases or decreases in road, rail or air traffic. There is evidence that, when exposure changes, people respond very differently than is anticipated by steady-state

exposure response curves. Brown and van Kamp (2009a and b) provide evidence of the existence of a change effect.

21) The approach to calculating the environmental burden of disease to transportation noise has been described.
22) The role of soundscape in annoyance outcomes from noise exposure has been briefly examined. These include restorative capacities of soundscapes on human health and well-being and the value of high quality acoustic environments to people otherwise living in noisy urban environments, and some evidence that a “quiet side of building” may reduce annoyance from otherwise high exposure to transport noise.

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WORKING PAPER

ON

A REVIEW OF CARDIOVASCULAR DISEASES/ RESPONSE WITH TRANSPORTATION NOISE

FOR

THE PROVISION OF SERVICE FOR THE STUDY OF HEALTH EFFECTS OF TRANSPORTATION NOISE IN HONG KONG

ENVIRONMENTAL PROTECTION DEPARTMENT, HKSAR GOVERNMENT

TENDER REF. AN 08-047

Prepared by Professor Tze Wai Wong (Author) and Ms. Andromeda Hin Shun Wong (Editor)
of School of Public Health and Primary Care of the Chinese University of Hong Kong

May 2011

CONTENTS

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1. Introduction

1.1 Study background

This review follows an earlier study, commissioned by the Environmental Protection Department (EPD), on environmental noise and non-auditory health effects (Wong, 2002). In that review – which covered research studies from 1980 to 2002 – seven major health outcomes were studied, namely: cardiovascular diseases/ response, sleep, annoyance, mental health, cognitive performance, stress hormones, and pregnancy outcomes. The current study, also commissioned by the EPD, focuses on the first three major outcomes. These were selected as they either show strong evidence of a link with noise exposure (e.g. sleep and environmental noise; blood pressure and occupational noise), or have a potentially great impact on public health (e.g. traffic noise exposure and cardiovascular diseases). This paper deals with cardiovascular diseases (CVD) and the response of the cardiovascular system to environmental noise from transportation sources. The following issues on noise and CVD will be addressed:

- Definition of noise effect outcomes – the meaning and interpretation;
- Description of the mechanisms of the effects of noise;
- Assessment of the evidence on the strength of the effects;
- Choice and measurement of the outcome variable(s);
- Factors moderating outcome effects;
- Current noise metrics/ scales for relating noise exposure to outcome; and
- Available exposure-response curves and known confounders.

1.2 Cardiovascular diseases and response

Diseases of the cardiovascular system are the leading causes of death in most developed countries. The commonest include ischaemic heart disease (IHD), hypertension (more specifically, essential hypertension), and cerebrovascular diseases, commonly known as 'stroke'.

IHD is caused by insufficient blood supply to the heart, and is the commonest form of heart diseases in adults today. Like many other chronic diseases, IHD is caused by multiple risk factors. Major and well-established risk factors for ischaemic heart disease include cholesterol and triglyceride levels in the blood, obesity, cigarette smoking, and hypertension, which is also an important risk factor of cerebrovascular diseases.

Hypertension is a clinical disease characterised by a persistently raised blood pressure. Blood pressure progressively increases with age. When a person's blood pressure exceeds a given limit, his or her condition is given the diagnostic label of 'hypertension'. The limit used for the definition is somewhat arbitrary. The Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC VI) (National Institutes of Health, 1997) defined and classified hypertension in adults as a systolic blood pressure of 140 mmHg or above, or a diastolic blood pressure of 90 mmHg or more.[*]

[*] The definition used in this report is based on the 1999 guidelines of the World Health Organization and International Society of Hypertension (Guidelines subcommittee. 1999 World Health Organization - International Society of Hypertension guidelines for the management of hypertension. *J Hypertens* 1999; 17: 151-183. Also available from http://www.eshonline.org/documents/whoish99.pdf). Earlier a definition of

‘Essential hypertension’ is a term that refers to hypertension that does not result from other well-known causes of hypertension, such as kidney diseases or tumour in the adrenal glands. The latter category is known as secondary hypertension; that is, hypertension due to a known cause. Some drugs and hormones, such as corticosteroids used for the treatment of certain diseases, can also lead to an increase in blood pressure. For over 90 % of patients suffering from hypertension the cause remains undetermined. Genetic factors are known to play an important role in essential hypertension (Matsubara, 2000). Other risk factors include obesity, salt intake, chronic stress, diet physical activity, alcohol intake and others (Schmieder et al, 1986; Pausova et al, 1999; Kulkarni et al, 1998).

Unlike hypertension, which can be objectively defined by the measurement of blood pressure, IHD can only be diagnosed clinically by symptoms of angina pectoris and by specific changes in the patient’s electrocardiograms (ECG). Angina typically manifests as chest pain on exertion, caused by the transient insufficiency of blood supply to the heart by the coronary arteries. Myocardial infarction (MI) is the most severe form of IHD, defined as the death of the heart muscles, which can be fatal. It is characterized by severe chest pain, changes in enzymes in the blood, and specific ECG changes. Both IHD and MI can be obtained from medical records or patients’ history, which may be subject to recall bias.

A cerebrovascular disease is a disease that affects an artery within the brain, or supplies blood to the brain. The most common cerebrovascular disease is atherosclerosis, where plaques (fatty deposits) form, leading to narrowing of the arteries. There may also be a defect or weakness in a blood vessel in the brain, which can cause an aneurysm (ballooning of an artery). Having a cerebrovascular disease increases one’s risk of having a stroke, which occurs when there is a sudden blockage, or rupture, of a blood vessel within the brain. [‡] A stroke is the sudden death of brain cells in a localized area due to inadequate blood flow.[§] It occurs when blood flow is interrupted to part of the brain. Without blood supply, brain cells die, causing paralysis, speech impairment, loss of memory and reasoning ability, coma, or death. A stroke is sometimes called a cerebrovascular accident (CVA). Modifiable risk factors for stroke includes hypertension, diabetes, hyperlipidemia, smoking, diseases of the carotid artery, atrial fibrillation and obesity (Romero et al, 2008).

1.3 Public health significance of environmental risk factors for cardiovascular diseases

Most of the major risk factors for cardiovascular diseases, in particular, ischaemic heart disease (IHD) and hypertension are lifestyle related: dietary habits and smoking are two obvious examples. Of greater concern to public health, however, is involuntary exposure (i.e. not by choice) to a prevalent environmental risk factor for cardiovascular disease, even if its influence – known as ‘effect size’ – might be much weaker than the lifestyle risk factors.[*]

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hypertension using cut-points ≥ 160 mmHg for systolic and ≥ 95 mmHg for diastolic blood pressure was used commonly.

[‡] As defined by NHS Choice (accessed at: http://www.nhs.uk/conditions/cerebrovascular-disease/Pages/Definition.aspx)

[§] As defined by Medical Dictionary (accessed at: http://medical-dictionary.thefreedictionary.com/stroke)

[*] Effect size can be expressed as a relative risk (RR) or as an odds ratio (OR), both of which are common measures of risk estimates in epidemiology. In this context, the ‘risk’ of a given disease is defined as the number of people with the disease, divided by the total population at risk (which includes both healthy and diseased individuals). The relative risk is thus the ratio of the disease risk among those exposed to a given risk factor, to the disease risk in those not exposed. The RR can be obtained in a follow-up or ‘cohort’ study. The ‘odds’ of disease is different from the ‘risk’; it is defined as the number of people with a disease,

This is because a much larger proportion of the population is exposed to an environmental condition than to a particular lifestyle. Thus, a prevalent environmental risk factor can cause disease in a large number of people, and make a substantial contribution to the overall cardiovascular disease burden, despite a small effect size at the individual level. In other words, many cases of cardiovascular diseases could be attributed to exposure to this environmental factor. The reduction in disease incidence that would be observed in the population, if this environmental factor could hypothetically be removed, is referred to as the ‘population attributable risk’ (PAR). The involuntary nature of their exposure is an additional justification for a vigorous scientific assessment of the risk which, if confirmed, must be controlled (‘risk reduction’) on a community-wide basis. Environmental noise is one postulated risk factor that belongs to this category; it might have a high PAR for cardiovascular diseases.

1.4 Mechanism of effect the stress model

Environmental noise has been incriminated by many researchers as a cause of high blood pressure and ischaemic heart disease. Many studies have shown that environmental noise exposure activates the central nervous system, and can trigger a host of changes in various subsystems in the human body that are identical to a stress response (Westman & Walters, 1981; Cohen et al, 1986). Noise is conceptualized as a stressor, inducing a stress reaction that leads to adverse health effects (Fig. 1a). A simplified model, adapted from Babisch et al (2001), is shown in Figure 1b.

As hypertension is defined by blood pressure, and is itself a risk factor for stroke, the hypothesis that noise might increase blood pressure might have important public health implications.

In terms of the disease mechanism, this hypothesis is biologically plausible. Noise, defined as unwanted sound, causes stress to the individual. It leads to the stimulation of the sympathetic nervous system and endocrine system, resulting in the secretion of stress hormones. This stimulation results in the following short-term physiological responses: an increase in the blood pressure and heart rate, and the narrowing of blood vessels (‘vasoconstriction’). However, whether long-term exposure to noise will eventually lead to a persistent, irreversible increase in blood pressure sufficiently high to be clinically classified as hypertension, or to a compromised coronary circulation that causes ischaemic heart disease, is much less certain. This has been the subject of much epidemiological and experimental research.

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divided by the number of people without it. Hence, the odds ratio is the ratio of the odds of disease among an exposed group, to the odds in a non-exposed group. The OR can be obtained from case-control studies. An RR or OR value of one means no additional risk; an RR or OR of greater than one denotes an increased risk. A value of less than one denotes a reduced risk.

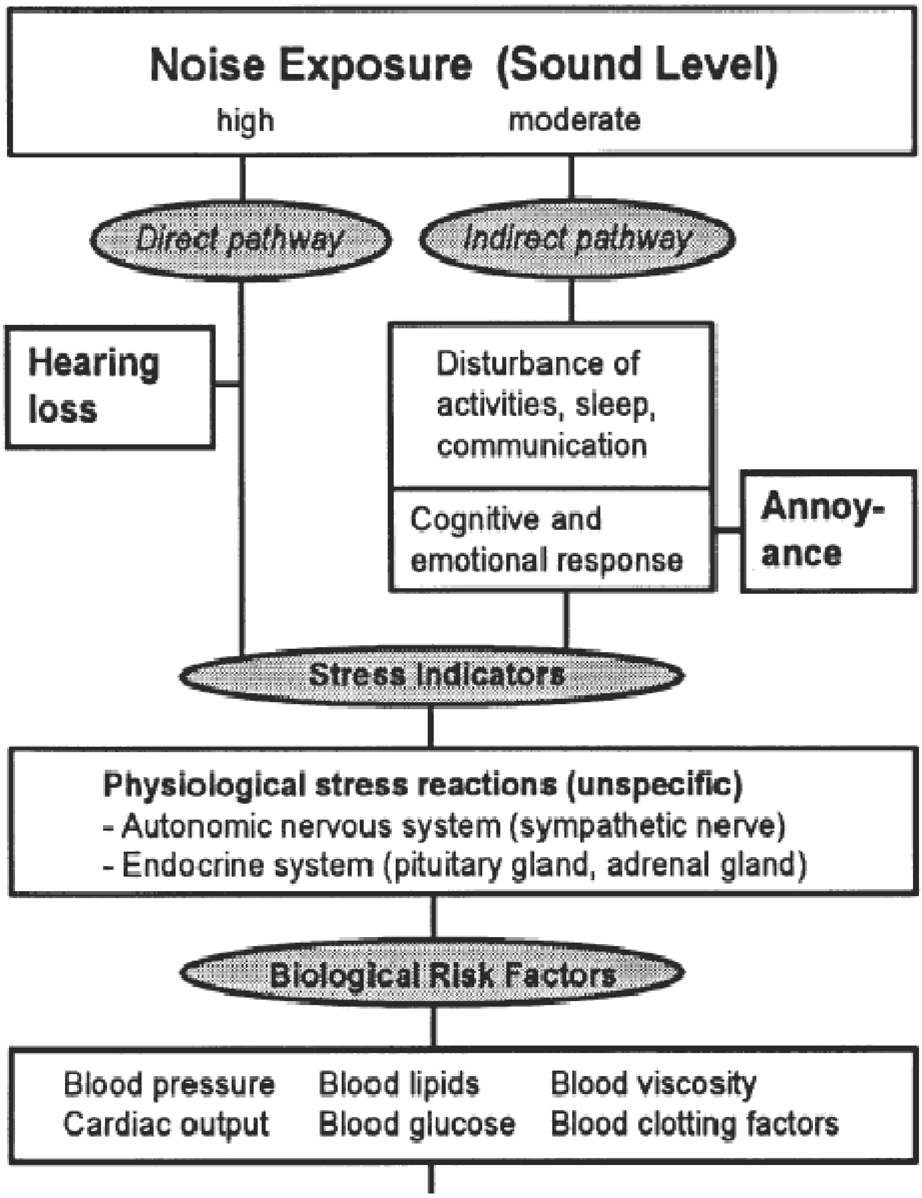

Figure 1a: Reaction model for hypothesis testing in epidemiological noise research (Source: Babisch et al, 2001)

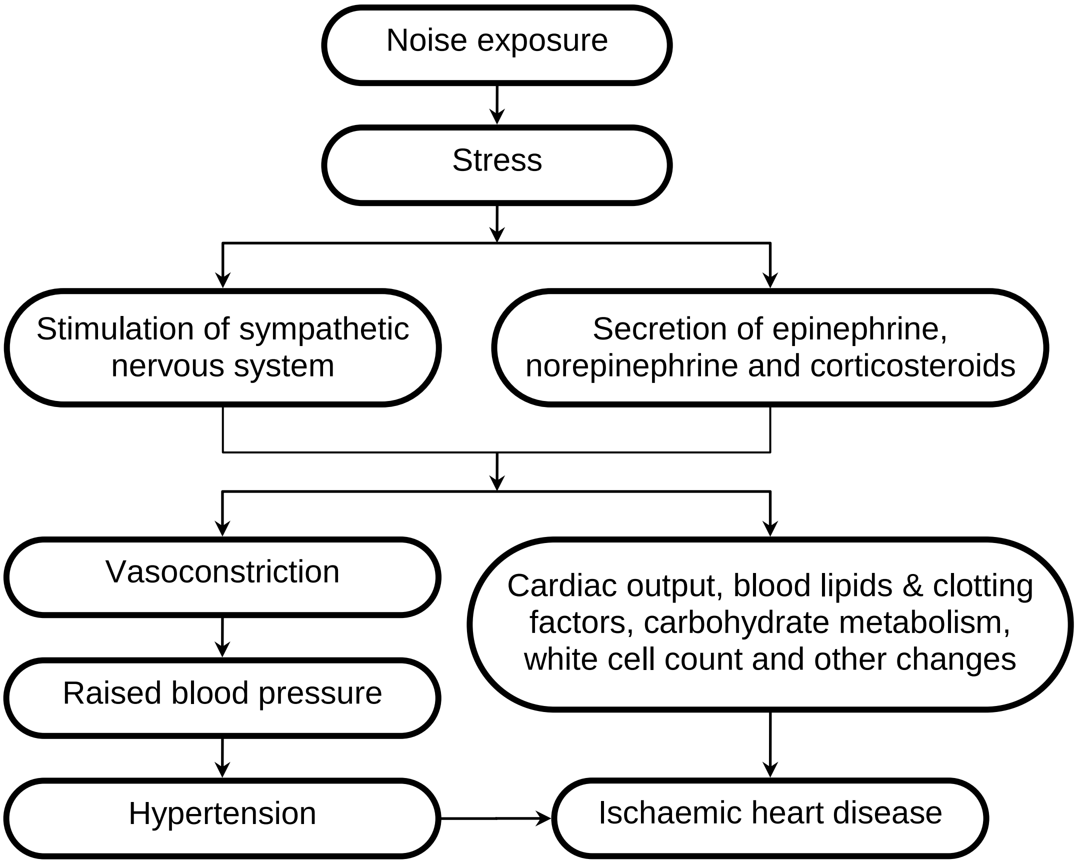

Figure 1b: The noise-stress-illness model, showing how noise may lead to cardiovascular diseases (Source: by the author, based on model by Babisch et al, 2001)

2. Method of assessment of evidence of the exposure-effect relationship

As the basis of this review, I started with the literature review commissioned by the Environmental Protection Department on environmental noise and non-auditory health effects (Wong, 2002) that covered original research published in English from 1980 to 2002. Further searches were performed on the database PubMed from 2003 to 2009. The keywords used in the search were: environmental noise/ road traffic noise/ aircraft noise and (i) heart disease, or (ii) cardiovascular disease, or (iii) hypertension.

3. Results

In addition to the papers reviewed in my earlier report, 48 papers and reports were studied. Evidence from the newer research papers was added to that obtained previously. One important example of such a paper was a large cohort study by Eriksson et al (2007), which strengthened the evidence of a causal relation between aircraft noise and hypertension. Besides papers containing original research, there were several review papers, meta-analysis papers, and reports that specifically dealt with transportation noise and cardiovascular risk (Babisch, 2000, 2006 & 2008; van Kempen et al, 2002). These review papers incorporated many conference proceedings, as well as European studies published in German and Dutch; none of these were readily accessible or available in the public domain, and had therefore not been covered in the 2002 report.

Two major cardiovascular diseases/ responses have been comprehensively reviewed: the effect of noise on blood pressure and hypertension, and on ischaemic heart disease. These will be presented separately below.

3.1 Blood pressure changes and hypertension

From my previous review (Wong, 2002), there is strong evidence of a link between high levels of noise exposure – mostly in occupational environments – and an increase in blood pressure. There is also some evidence in human experimental studies that short-term exposure to intense noise increases heart rate, cardiac output, and blood pressure (Carter & Beh, 1989; Ising et al 1980; Curio & Michalak, 1993; Sakamoto et al 1997). However, whether the increase in blood pressure predisposes to hypertension in the long run could not be elucidated from these studies.

For transportation noise and cardiovascular risk, the 2002 review mentioned significant associations between noise and blood pressure/ hypertension, as reported from two large, population-based cross-sectional (observational) studies: the Bratislava study of pre-school children (Regecova & Kellerova, 1995) and the Stockholm study of adults (Rosenlund et al, 2001). In the more recent review by Babisch (2006), similar epidemiological evidence was separately assessed for children and adults, and sorted by aircraft and road traffic noise on two outcomes – namely, blood pressure/ hypertension and ischaemic heart disease.

3.1.1 Studies on children

3.1.1.1 Aircraft noise and children's blood pressure

In the review by Babisch (2006), a study of children from schools and homes near Los Angeles airport (Cohen et al, 1980 & 1981) found small differences in blood pressure (3–7 mmHg) between groups exposed to different levels of air traffic noise. The study might be affected by selection bias (due to selective migration during the follow-up study), and confounded by inadequate control of ethnicity. Furthermore, the small difference in mean blood pressure was of little clinical significance.

Another study of the effect of aircraft noise, on children living near Munich International Airport, reported a borderline significant difference of 2 mmHg in systolic blood pressure between the noise-exposed ($L_{eq\ 24h}$ = 68 dBA) versus the non-exposed ($L_{eq\ 24h}$ = 59 dBA), and no difference in diastolic pressure (Evans et al, 1995). The follow-up study showed no difference in blood pressure (Evans et al, 1998).

The Sydney airport study on schoolchildren (Morrell et al, 1998 & 2000) showed non-significant changes in the children's systolic and diastolic blood pressure with aircraft noise, corresponding to mean blood pressure differences of 1 mmHg across the whole noise range. This is too small to be considered of clinical importance. Furthermore, the variation in blood pressure over time was not associated with noise levels. A German paper reported that exposure to noise from low-flying military aircraft (L_{max} = 125 dBA) was associated with a higher systolic blood pressure of up to 9 mmHg in girls, but not in boys (Ising et al, 1990). This finding was not confirmed in the main study by the same authors, or in other studies (van Kempen et al, 2006).

3.1.1.2 Road traffic noise and children's blood pressure

The Bratislava study was a cross-sectional study of 1,542 pre-school children, aged 3–7 years, exposed to high-level urban traffic noise in the vicinity of their kindergartens (Regecova & Kellerova, 1995). Parents were asked to complete a questionnaire on socio-demographic details, the health status and personality of their child, outdoor noise levels at home, and their length of residence. The children's cardiovascular variables were measured at their kindergartens. The mean systolic and diastolic blood pressure ($p<0.001$) were significantly higher ($p<0.001$) in children whose kindergartens were exposed to noisy (61–69 dBA) or very noisy (≥ 70 dBA) traffic, compared with those in a quiet environment (≤ 60 dBA). There was also a significant decrease in the children's heart rates with higher traffic noise, either at kindergarten (≥ 61 dBA; $p<0.001$) or at home (≥ 70 dBA; $p<0.05$). This was most likely caused by 'reflex inhibitory baroreceptor mechanisms': a rise in blood pressure stimulates the pressure-sensitive receptors in the blood vessels, which transmit signals to the heart, thereby slowing the heart rate. A dose-response relationship was found, adding support to a possible causal role of environmental noise on blood pressure. Using two-factor analysis of variance, the highest mean blood pressure levels – and the lowest heart rates – were found in children who both resided and attended kindergartens in noisy areas. Children living in quiet residences but who attended noisy kindergartens had the second highest blood pressure levels, followed by children who attended quiet kindergartens but lived in noisy areas. The lowest mean blood pressure values were found in children who enjoyed quiet environments at home and at kindergarten. The influence of noise on blood pressure was more apparent with the increasing age of the children. Results showed that traffic noise at kindergarten had a greater impact on the children's cardiovascular health than traffic noise at home. However, eighty percent of the subjects were attending kindergartens situated in areas where noise levels were above L_{eq} 61 dBA (24 h), and 46% of these children also lived in noisy residences (> 61 dBA); this population characteristic might skew the results towards a more positive association between noise and cardiovascular effects. A major concern of this study is the uncertain clinical significance of the observed higher blood pressure, and whether this could be linked to adult hypertension.

The blood pressure of children exposed to road traffic noise was also assessed by a study in Halle, Germany (Karsdorf & Klappach, 1968). An increase of up to 10 mmHg was found in the group with the highest exposure. An exposure-effect relation was observed. However, social class as a confounder was not studied, and children with blood pressure-related diseases were excluded from the analysis. In a study of children in Tyrol, Austria (Lercher, 1992a & 1992b), a lower, non-significant increase in blood pressure was found in noise-exposed children. Another study in the same region showed a marginally higher systolic blood pressure of borderline significance in children exposed to higher levels of road and railway noise (L_{DN} > 60 dBA) compared to those less exposed (Evans et al, 2001; Lercher et al, 2002).

The conclusion in the review by Babisch (2006, 2009) on the effect of aircraft and road traffic noise on children was that the significance of a higher blood pressure in children, in terms of the future risk of hypertension, is still unknown. There are two reasons for this uncertainty. First, the increase in blood pressure may be a transient, reversible response. There is crude evidence that supports this hypothesis (Morrell et al, 2000). Conversely, there is no evidence that any noise-induced increase in blood pressure in children is associated with hypertension in later life. Secondly, the blood pressure difference of only a few mmHg, which was reported in most such studies (with the possible exception of the early study by Karsdorf and Klappach, and that by Ising on girls), was too small to be of any clinical significance. Nevertheless, there is some evidence that blood pressure level at an early age is an important predictor of blood pressure at a later stage (Gillman et al, 1992; Yong et al, 1993; Tate et al, 1995). Babisch also pointed out that, while studies on aircraft noise focused on exposure at school, road traffic noise studies refer to exposure at home. Different mechanisms – disturbed learning and concentration, versus disturbed relaxation and sleep – may be involved in the two sites. He concluded by quoting Evans and Lepore (1993): "We know essentially nothing about the long-term consequences of early noise exposure on developing cardiovascular systems. The degree of blood pressure elevation is small. The clinical significance of such changes in childhood blood pressure is difficult to determine. The ranges of blood pressure among noise-exposed children are within the normal levels and do not suggest hypertension. The extent of blood pressure elevations found from chronic exposure is probably not significant for children during their youth…" This statement is based on fact and appears reasonable; but Babisch (still quoting Evans and Lepore) then adds that even such small increases in blood pressure during childhood "could portend elevations later in life that might be health damaging." In my opinion, the potential damage to health suggested by this final statement lacks supporting evidence.

3.1.2 Studies on adults

3.1.2.1 Aircraft noise and adult's blood pressure/ hypertension

The Stockholm airport study reported a higher prevalence of doctor-diagnosed hypertension in adults exposed to aircraft noise (Rosenlund et al, 2001). In this cross-sectional study, two random samples of subjects aged 19–80 years were surveyed. The authors had recruited 266 residents who lived close to Stockholm-Arlanda Airport, with maximum aircraft noise level (L_{max}) greater than 72 dBA; and 2,693 subjects from other parts of Stockholm county, with energy-averaged aircraft noise levels (L_{eq}) exceeding 55 dBA. The prevalence of hypertension was higher among those exposed to aircraft noise levels of at least 55 dBA L_{eq}, or to L_{max} above 72 dBA. After adjusting for age, sex, smoking and education, the prevalence odds ratio for hypertension was 1.6 (95% CI: 1.0–2.5) at L_{eq} > 55 dBA, and 1.8 (95% CI: 1.1–2.8) at L_{max} > 72 dBA. The study also reported the risk of hypertension to be greater in older subjects and in those with no hearing disabilities. Some important details, such as body mass index or a family history of hypertension, were not questioned in the survey, which may potentially have confounded the results. One limitation of this study was that hypertension was self-reported; the results might therefore have been subject to recall bias.

A similar, much larger study was conducted on 11,812 residents living within a 25 km radius of Amsterdam Airport Schiphol (Franssen et al, 2004). The subjects' general health status, use of sleeping medication, and use of medication for cardiovascular diseases were assessed; an association was sought between these parameters and aircraft noise exposure. The study reported statistically significant adjusted odds ratios, ranging from 1.02 to 2.34 per 10 dBA increase in L_{DEN}. A small fraction of the prevalence of poor self-rated health (0.13), medication for cardiovascular diseases or increased blood pressure (0.08), and sleep medication or sedatives (0.22), could be attributed to aircraft noise.[*] The results suggested associations between community exposure to aircraft noise and three health indicators: poor health status, the use of sleep medication, and the use of medication for cardiovascular diseases. However, the same limitations as the Stockholm airport study apply here, as the health indicators were self-reported.

A recent cohort study (Eriksson et al, 2007) on aircraft noise and the incidence of hypertension suggested that long-term exposure to aircraft noise may increase the risk of hypertension in middle-aged Swedish men. A total of 2,754 men in four municipalities around Stockholm-Arlanda Airport were followed up between 1992–1994 and 2002–2004. Residential aircraft noise exposure was assessed by geographical information system techniques among those living near the airport. Incident cases of hypertension were identified by physical examinations, including blood pressure measurements, and questionnaires on diagnosis and treatment for hypertension. Data from 2,027 of the subjects, who completed the follow-up examinations, were not treated for hypertension, and had a normal blood pressure level (below 140/90 mmHg) at enrolment, were analysed. For subjects exposed to $L_{eq} > 50$ dBA, the adjusted relative risk (RR) for hypertension was 1.19 (95% CI: 1.03–1.37). A dose-response relation was observed. The findings were similar for maximum aircraft noise levels: the RR for those exposed above 70 dBA was 1.2 (95% CI: 1.03–1.40). Stronger associations were found among older subjects, non-smokers, those with normal glucose tolerance, and those not annoyed by noise from other sources. The strengths of this study included the longitudinal design, the objective assessment of both noise exposure and disease outcome, and the adjustment for a large number of potential confounding factors. Residual confounding, exposure and disease misclassification, and selection bias may still be present. This study adds to the evidence from earlier cross-sectional studies (Rosenlund et al, 2001; Franssen et al, 2004). A more recent HYENA (Hypertension and Exposure to Noise near Airports) study found significant exposure-response relationships between night-time aircrafts as well as daily road traffic noise exposure and risk of hypertension (Jarup et al, 2008). The OR[**] (95% CI) per 10 dB increase in noise exposure was 1.14 (1.012-1.086) for L_{NIGHT} aircraft noise. Major confounders – country, sex, age, alcohol intake, body mass index, physical activity and education – were controlled. Smoking was found to have little impact, while air pollution was not adjusted. Within the framework of the HYENA study, a sample of 140 subjects living near airports in Europe was studied on acute effects of night-time noise on their blood pressure. A significant increase in systolic and diastolic blood pressure of 6.2 mmHg (0.63-12) and 7.4 mmHg (3.1, 12) respectively was observed over 15 minute intervals in which an aircraft event occurred (Haralabidis et al, 2008).

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[*] The decimal numbers in parenthesis denote the 'attributable fractions' of the health effects. The attributable fraction is defined as the prevalence of health effects caused by aircraft noise, divided by the overall prevalence.
[**] Both ORs and RRs have been used as risk estimates. There are differences in the mathematical derivation of the two estimates. Whether a paper reports ORs or RRs depends on the study design. Case-control studies yield risk estimates in ORs, while cohort studies yield RRs. In this section, the studies using OR and RR as risk estimates are broadly in agreement. See also footnote on 'effect size', on p4 and 5.

Two studies on adults that were reported in Babisch's 2006 review yielded conflicting results. The first was on women in Fukuoka, Japan, where 469 women living near Fukuoka Airport and 1,177 women residing in suburban Fukuoka showed no significant association of systolic and diastolic blood pressure with aircraft noise (Goto & Kaneko, 2002). The mean systolic blood pressure was higher by 4 mmHg in the exposed group ($L_{DN} \geq 70$ dBA) than in the reference group ($L_{DN} < 60$ dBA), but the difference disappeared during the follow-up period. The diastolic blood pressure in the reference group was 4 mmHg higher than the exposed group. The authors concluded that "there was no obvious difference in blood pressure caused by aircraft noise". The second study involved 29,000 residents of Okinawa who lived near a military airfield (Matsui et al, 2004). Here, a clear dose-response relationship between blood pressure and noise exposure, with a highly significant ($p<0.0002$) trend, was found. The odds ratio of hypertension for the highest noise-exposed group ($L_{DN} > 70$ dB) was 1.4, as compared to the reference group ($L_{DN} = 60$–65 dB). There were significant reductions in lipid concentrations (total cholesterol, LDL, and HDL) with the increase in aircraft noise level ($p<0.0001$). The study used multiple logistic regression analysis with adjustment for age, sex, BMI and their interaction terms as confounders.

An earlier study of aircraft noise around the old Munich airport (Eiff et al, 1974; Rohrmann, 1974) reported a mean diastolic blood pressure difference of 3 mmHg – too small to be clinically significant – between adults exposed to the highest noise level and those least exposed. A U-shaped association was observed across noise levels. Studies on low-flying military aircraft noise and mean blood pressure also yielded no differences between the exposed and control groups (Schulte & Otten, 1993).

The above review on aircraft noise, raised mean blood pressure, and risk of hypertension yielded somewhat different conclusions. While results of studies on raised blood pressure were not conclusive – most reported clinically insignificant changes in blood pressure levels – there is more definitive evidence on noise as a risk factor for hypertension. The Stockholm study is the only cohort study on aircraft noise and hypertension (Eriksson et al, 2007). Not only do the findings confirm earlier cross-sectional studies; this study also demonstrates statistically significant RRs of hypertension from aircraft noise exposure, which are of sufficient magnitude to be of public health importance. The study also offers evidence of an exposure-response relation – an important criterion for a cause-effect relationship.

A quantitative meta-analysis by van Kempen et al (2002), made on studies about cardiovascular risk and noise exposure that were published between 1970 and 1999, found a significant association for both occupational noise exposure and air traffic noise exposure with hypertension. The RRs per 5 dBA noise increase were 1.14 (95% CI: 1.01–1.29) and 1.26 (95% CI: 1.14–1.39) respectively. Aircraft noise was positively associated with doctor-consultation, the use of cardiovascular medicines, and chest pain (a symptom of ischaemic heart disease, formally referred to as 'angina pectoris'). Note that this meta-analysis did not include the more recent Stockholm cohort study on aircraft noise and the incidence of hypertension described earlier (Eriksson et al, 2007).

To conclude, there is increasing evidence for an association between aircraft noise and hypertension, with significant RRs from 1.4–2.1 for subjects exposed to daytime noise (L_{DAY}) of 60–70 dBA or more. Swedish studies found an RR of 1.6 at even lower noise levels (> 55 dBA). An important limitation to these findings is that there are many confounding factors for hypertension, many which are not adjusted for, with the exception of the more recent HYENA study (Jarup et al, 2008). There seems little evidence, however, of the link between aircraft noise and mean blood pressure. One must, however, understand the difference between mean blood pressure and hypertension. Some studies specifically exclude subjects with hypertension when assessing their mean blood pressure.

3.1.2.2 Road traffic noise and adult's blood pressure/ hypertension

Babisch (2006) reviewed a study in Bonn, Germany (Eiff & Neus, 1980; Eiff et al, 1981; Neus et al, 1983) that suggested a significant risk of hypertension, with RR = 1.5, for subjects exposed to traffic noise at $L_{DAY} \geq 65$ dBA. Another study in Erfurt reported a significant relative risk of 2.4 for subjects exposed to $L_{DAY} = 75$ dB(AI) compared to controls, who were exposed to $L_{DAY} = 67$ dB(AI) (Schulze et al, 1983). However, the risk estimates in this study were expressed as proportional morbidity ratios (PMRs), which were calculated by dividing the incidence of treatment for hypertension by the incidence of treatment for other diseases. The use of PMRs had severe limitations, as they can reflect not only changes in the occurrence of hypertension, but also in the occurrence of other diseases.

Several other studies supported the hypothesis that road traffic noise does indeed have a health impact. The cross-sectional study by Bluhm et al (1998) in Sollentuna, Sweden, showed a higher prevalence of hypertension among the noise-exposed group. The noise levels of $L_{eq\,24h}$ in this group ranged from 40–65 dBA for road traffic noise, and from 55–65 dBA for train noise exposure. The confounder-adjusted RR (at 1.8) was significant for the road traffic exposed group, at $L_{eq\,24h}$ >50 dBA, when compared with the group exposed to $L_{eq\,24h}$ <50 dBA. The effect was only seen in women (RR = 3.3), but not in men (RR = 1.0), which might have been due to higher exposure at home in the former. However, the results were opposite for train noise, with the exposed group being at lower risk of hypertension than the control group (RR = 0.8), although this difference was not significant. Other outcomes in this study, such as the prevalence of annoyance and sleep disturbance, were higher in the group exposed to train noise, which was in accordance with the hypothesis. A re-analysis of the road noise sample found a non-significant RR of 1.5 (men, 1.4; women, 1.8) for hypertension in the total sample. Among residents for 10 years or more, RR = 2.4 and was statistically significant.

A health survey in Spandau, Germany showed an increasing period prevalence and lifetime prevalence of hypertension, at road traffic noise levels from L_{DAY} <55 to 70 dBA, and L_{NIGHT} <50 to 65 dBA (Maschke et al, 2003). The relative risks were 1.5 (L_{DAY} >65 dBA) and 1.9 (L_{NIGHT} > 55 dBA). The risk of night-time noise exposure in the bedroom was significant.

A cross-sectional study in Berlin (Babisch et al, 1992) showed a significant RR of 1.3 among those disturbed by traffic noise. Like all cross-sectional studies, this study was susceptible to recall bias due to over-reporting. Another German cohort study (Muller et al, 1994; Bellach et al, 1995) showed an RR of 0.9 (males: 1.2; females: 0.9) for 'global' disturbance (affected by traffic noise). However, a significant RR of 2.3 for hypertension was found for those with reported sleep disturbance. Belojevic and Saric-Tanaskovic (2002) reported significant odds ratios for self-reported hypertension (OR = 1.8; 95% CI: 1.0–2.4) and myocardial infarction (OR = 1.7; 95% CI: 1.0–2.9) in male subjects who were very much or extremely noise-disturbed, compared with those who were slightly or not annoyed. OR among females were not significant. While individual studies yielded inconsistent results, a study of eight cities study in Europe (the LARES study) showed a higher morbidity among the noise-annoyed group compared with those not annoyed (Niemann & Maschke, 2004). Self-reported hypertension was significantly more prevalent in subjects annoyed by traffic noise (RR = 1.6) and neighbourhood noise (RR = 1.7). Sleep disturbed subjects had a RR of 1.5.

Studies in the Netherlands, Germany, and Austria, where potential confounding factors were better controlled, were mostly non-significant (Knipschild & Sallé, 1979; Knipschild et al, 1984; Herbold et al, 1989). More recent studies by Yoshida et al (1997) and Lercher et al (2000) also did not support the hypothesis. Two studies on annoyance and hypertension, in Amsterdam, the Netherlands, and in Tyrol, Austria, (Knipschild et al, 1984; Evans et al, 1998) showed no association between the prevalence of hypertension and the subjects' rating of annoyance from road traffic noise.

More recently, the HYENA study in six major European airports (Jarup et al, 2008), referred to under aircraft noise and hypertension in Section 3.1.2.1, showed significant associations between between road traffic noise ($L_{Aeq,\ 24h}$) and hypertension. This study provides good evidence of an excess risk of hypertension and long-term exposure to road traffic noise. An OR of 1.097 (95% CI: 1.003-1.201) was found for a 10 dB increase in road traffic noise level. Several important confounding factors were controlled. The weaknesses of this study include the low response rates in some countries (30% in Germany, Italy and the U.K.), the cross-sectional study design, and the lack of control of air pollutants as confounders.

In a postal questionnaire survey (with a high response rate of 71%) of a population affected by both highway and railway noise in Lerum, Sweden, a significant association was found between physician-diagnosed hypertension and antihypertensive medication and high traffic noise level (56 – 70 dBA) among men. The OR for hypertension (adjusted for age, sex, body mass index and hereditary for hypertension) was 1.9 (95% CI: 1.1 – 3.5). An exposure-response relationship was also demonstrated (Barregard et al, 2009).

Another recent cross-sectional study on road traffic noise and self-reported hypertension among 24,238 adults in southern Sweden showed similar results, with an OR of 1.06 (95%CI: 1.00-1.13) for a 10 dB(A) increase in $L_{Aeq\ 24\ h}$. Insignificant ORs of about 1.1 were found at noise level categories of 45 – 64 dBA. The OR was significant (OR=1.45; 95% CI: 1.04-2.02) at >64 dBA. The effect was modified by age. Among those aged 40 – 59 years, significant ORs (1.27 and 1.91 respectively) were observed of those exposed to 60-64 dB(A) and above 64 dB(A) (Bodin et al, 2009). The bias owing to self-reporting of hypertension would probably result in under-reporting, which would bias the results 'towards the null' (i.e., a tendency to miss significant findings). Air pollution was not adjusted for. Although air pollution is associated with cardiovascular mortalities, there is currently no epidemiological evidence of a link between air pollution and hypertension.

In summary, while earlier studies have yielded inconsistent results, there is growing evidence of a link between hypertension and road traffic noise in more recent studies. Both the HYENA study and the two studies in Sweden showed significant ORs after adjusting for major confounding factors. Subjective ratings of disturbance by traffic noise show a consistent association with the prevalence of hypertension. However, these studies are more prone to recall bias and therefore considered to be less valid.

3.2 Ischaemic heart disease and noise

Epidemiological studies on noise and ischaemic heart disease (IHD) usually employ one or several criteria for IHD that may differ among researchers. In cross-sectional studies, the prevalence of IHD can be determined by criteria such as symptoms of angina pectoris, myocardial infarction (MI), changes in cardiac enzymes in the blood, or electrocardiographic (ECG) abnormalities. These are commonly obtained either through subjects' reports of their doctors' diagnoses, or through hospital records. For cohort studies, IHD incidence is obtained by following up subjects over a specified period of time. Disease status is determined by reviewing hospital records or clinical interviews, either periodically or at the end of the study period.

In my earlier review, I stated that "the best evidence was provided by a large, 10-year cohort study that reported no significant risk of ischaemic heart disease" (Wong, 2002). In the Caerphilly and Speedwell studies, which examined the potential relationship between the incidence of IHD and chronic traffic noise exposure, 4,860 middle-aged men were followed up over a 10-year period (Babisch et al, 1999). Noise measurements were performed in every street where the subjects lived, and the noise emission levels ranged from L_{eq} 51 to 70 dBA (6–22 h) at both locations. Subjects completed noise questionnaires and were examined in clinics. The incidence of IHD was recorded, including deaths, non-fatal MI, and electrocardiogram and cardiac enzyme changes. The adjusted relative risk of IHD incidence for men living in the highest traffic noise areas of 66–70 dBA were 1.1 (95% CI: 0.6–1.9) and 0.9 (95% CI: 0.6–1.4) in Caerphilly and Speedwell, respectively, with reference to the lowest traffic noise category of 51–55 dBA. Note that in both cohorts, a relative risk of IHD greater than one was observed only in the highest noise category. Neither relative risk values were statistically significant, even when adjusted for potential confounding factors of age, social class, marital status, smoking, body mass index, family history of myocardial infarction, employment status, physical activity, prevalence of ischaemic heart disease and pre-existing health conditions. When room orientation and window opening habits were considered, the adjusted relative risks of IHD remained insignificant. The authors concluded that they could not "deduce that traffic noise level increases the risk for MI or any other form of IHD", based on their study alone.

Prior to this cohort study, the meta-analysis by van Kempen et al (2002) yielded statistically significant summary risk estimates for cross-sectional studies ($RR_{5dBA} = 1.09$; 95% CI: 1.05–1.13). However, when the results of the 10-year cohort study were added, the effect of road traffic noise on IHD became insignificant ($RR_{5dBA} = 0.97$; 95% CI: 0.90–1.04). The association between the prevalence or incidence of myocardial infarction and road traffic noise was, likewise, not significant.

Babisch (2006) reviewed 12 cross-sectional studies (Knipschild, 1977a & b; Knipschild & Salle, 1979; Eiff & Neus, 1980; Eiff, et al, 1981; Neus, et al, 1983; Altena, 1989; Pulles et al, 1990; Babisch, et al, 1988; Babisch, et al, 1992, 1993a & b; Lercher, 1992a & 1996; Lercher & Kofler, 1995; Yoshida, et al, 1997; Maschke, et al, 2003; Bluhm, et al, 2004) and 7 case-control/ cohort studies (Schulze, et al, 1983; Babisch, et al, 1992, 1999, 2003, 2005) on community noise and ischaemic heart disease . In the 1970s cross-sectional study and survey on aircraft noise in Amsterdam, significant prevalence ratios (1.0–1.9) were found for different IHD endpoints (Knipschild, 1977a & 1977b). A later cross-sectional study on aircraft noise and IHD, carried out in four Dutch cities (Groningen, Twenthe, Leeuwarden and Amsterdam), found prevalence ratios greater than one for noise level categories higher than 55 dBA (Altena, 1989; Pulles et al, 1990). However, no dose-response relationship was found across the noise level categories, and the RR for subjects in the highest category was 0.9, lower than in the reference category. The response rates were low, at about 43%. Subjects treated for hypertension were excluded from analysis; this might have resulted in selection bias, as hypertension is a risk factor for IHD.

The Spandau health study, primarily on road traffic noise but which also included aircraft noise, found a period prevalence (past 2 years) of self-reports of doctor-diagnosed angina to be higher among the noise-exposed (RR = 1.6 at a noise level of $L_{eq(4)}$ > 62 dBA), which was not significant (Maschke et al, 2003). For myocardial infarction, the risk was lower (RR = 0.4) in the noise-exposed group. The Stockholm study, on the other hand, yielded opposite results – a higher risk of MI (RR = 2.6) and a lower risk of angina pectoris (RR = 0.9) among those exposed to noise above 55 dBA (Bluhm et al, 2004). These studies seem inconclusive as to the cardiovascular effects of aircraft noise.

For road traffic noise, the Tokyo study on subjectively reported heart disease did have significant results, with an OR of 3.1 at a noise level of L_{24h} > 65dBA (Yoshida et al, 1997). The Tyrol study showed a significant RR (RR = 2.1) for angina pectoris but a non-significant RR of 0.8 for myocardial infarction, for noise exposure higher than 60 dBA (Lercher, 1992a; Lercher & Kofler, 1995; Lercher, 1996).

Several cross-sectional studies – in Bonn (Eiff & Neus, 1980; Eiff et al, 1981; Neus et al, 1983), Berlin (Babisch et al, 1992 & 1994), Caerphilly (Babisch et al, 1988; Babisch et al, 1993a), and Speedwell (Babisch et al, 1993a & 1993b), all yielded positive but statistically insignificant results. The RRs were consistently higher than one, ranging from 1.1 to 1.4 (for outdoor noise levels of L_{DAY} > 65–70 dBA). The Spandau study (Maschke et al, 2003) showed a high, but insignificant RR (> 3) for road traffic noise L_{DAY} > 60 dBA and L_{NIGHT} > 50 dBA. The study in Doetinchem, the Netherlands, also yielded an insignificant RR at 1.1 for ECG abnormalities, and a RR of 0.7 for angina at a noise level of L_{DAY} > 65 dBA (Knipschild & Sallé, 1979). The Dutch four cities study on IHD (Altena, 1989; Pulles et al, 1990) showed no association between road traffic noise and IHD, as defined by clinical interviews and ECGs.

Most longitudinal studies on IHD incidence and road traffic noise showed non-significant effects or no effects. The Berlin hospital- and population-based case-control studies (Babisch et al, 1992 & 1994) yielded insignificant ORs of 1.2–1.3 for noise exposure of L_{DAY} >70 dBA. The sample size of the population-based case-control study was large, and the risk increased among those with 15 or more years of exposure duration. The Caerphilly and Speedwell cohort studies yielded no effect of outdoor, address-related noise levels (Babisch et al, 1999). However, the 6-year follow-up analysis of the reconstructed cohort, with additional information on residence time, window-opening habits, and room orientation in the exposure assessment, yielded non-significant but raised RRs of 1.2–1.6, when comparing subjects exposed to L_{DAY} = 66–70 dBA and those exposed to L_{DAY} = 51–55 dBA (Babisch et al, 1999 & 2003). A relationship between the duration of exposure and IHD risk was found for this highest noise category, with an RR of between 1.01 and 1.02 per year.

In the Noise and Risk of Myocardial Infarction (NaRoMI) study of 4,115 patients (3,054 men and 1,061 women) from 32 hospitals in Berlin, Willich et al (2006) reported that there was a marginally increased risk of MI associated with annoyance by environmental noise (from all sources) in women (adjusted OR = 1.47; 95% CI: 0.95–2.25) but not in men. The risk was not associated with annoyance by work noise. Environmental noise levels (assessed using traffic noise maps as a proxy) were associated with increased risks in both men (OR = 1.46; 95% CI: 1.02–2.09) and women (OR = 3.36; 95% CI: 1.40–8.06), and work noise levels in men only (OR = 1.31; 95% CI: 1.01–1.70). He concluded that chronic noise burden was associated with MI and that the risk was more closely associated with noise levels than with subjective annoyance.

The paper by Babisch et al (2005), which is also based on the NaRoMI study, used a similar approach to the follow-up analysis of the Caerphilly and Speedwell studies (Babisch et al, 2003). The authors reported no increase in cardiovascular risk at a noise level of 60 dB ($L_{DAY\ 0600\text{-}2200}$). However, a dose-response relationship in RRs was found at the noise level L_{DAY} < 60–75 dBA, with an RR of 1.3 for subjects exposed to the highest noise category (>70 dBA). This value increased to 1.8 for those subjects who have lived at their residence for 10 years or more.

In an ecological study on traffic noise and myocardial infarction (MI) risk in Lithuania (Grazuleviciene et al, 2004), the age-adjusted MI incidence per 1,000 increased by increasing noise exposure. The result for the overall age group (25-64) was non-significant (RR= 1.33;95% CI: 0.76-2.32), but that for those aged 55-64 years was significant (RR=1.92; 95% CI: 1.00-3.67). However, ecological studies are prone to errors, the so-called ‘ecological fallacies’ that may arise from misclassifications and confounding factors that cannot be adjusted for.

According to a recent U.K. Report (Health Protection Agency, 2009), there is a significant risk of IHD (RR = 1.09; 95% CI: 1.05-1.13) from traffic noise. The report further quoted an RR of 1.26 (95% CI: 1.14-1.39) for aircraft noise from only one study, which therefore cannot be relied on. The report also reviewed the meta-analysis by Babisch (2005), but noted that even at the highest noise category, the RR still spans zero (i.e., statistically insignificant). Effects of traffic noise on risk factors for IHD, such as serum total cholesterol, triglycerides, blood platelet counts, glucose levels and blood viscosity are inconsistent. There is also insufficient evidence on the link between noise and cardiac arrhythmia (Brenner et al, 1993).

To sum up, the evidence of a link between both road traffic and aircraft noise and IHD is weak. Inconsistencies in the risk estimates are common, especially in cross-sectional studies. That cohort studies, or even meta-analyses of results from several studies, did not produce significant RRs implies that the observed association between traffic noise and IHD may be explained by chance or confounding factors such as air pollution. Further studies on the joint effects of air pollution and environmental noise on cardiovascular diseases is expected to clarify the complex relationship. Tables summarizing the findings of the papers reviewed in this Report are shown at Appendix 1.

3.3 Confounding factors and effect modifiers of the association between noise and cardiovascular diseases

A confounding factor is a factor that either creates a spurious association between an exposure (cause) and a health outcome (effect), or masks a true underlying association. A confounding factor must be an independent risk factor for the health outcome, must not be part of the pathway between cause and effect, and must be unevenly distributed between the comparison groups, which comprise the exposed and non-exposed groups in cross-sectional and cohort studies, or the ‘cases’ (diseased group) and ‘controls’ (healthy group) in case-control studies.

By contrast, an effect modifier is a factor which alters the effect of a risk factor. In other words, the magnitude of risk estimates like OR and RR will vary across the different categories of the effect modifier, such as its presence or absence.

Some studies have shown that the noise and cardiovascular diseases relationship is stronger among those who are annoyed by environmental noise (Niemann & Maschke, 2004; Willich et al 2006). Other studies have shown this relationship in noise-sensitive individuals only. In a Finnish mortality study of a cohort of twins, (Heinonen-Guzejev et al, 2007), the risk of cardiovascular mortality was significantly higher among noise-sensitive women (hazard ratio = 1.80; 95% CI: 1.07–3.04), but not in noise-sensitive men.

Most studies on road traffic noise and IHD did not adjust for differences in the air pollutant concentrations that noise-exposed participants and their control groups were subjected to. In other words, air pollution may well have been the confounder that accounted for the apparent association between road traffic noise and cardiovascular effects. While there is substantial evidence that air pollution is associated with cardiovascular mortality, independent of environmental noise, there is little evidence that the converse is also true. Note that this explanation, however, does not apply to aircraft noise and cardiovascular effects, as pollutants from aircraft disperse at high altitudes and do not directly affect the population below. As mentioned in section 3.2, the joint effect of environmental noise and air pollution on cardiovascular diseases has been the subject of recent studies (Jarup et al, 2006; Schwela et al, 2005; de Kluizenaar et al, 2007). These studies should be able to determine whether the observed association between environmental noise and cardiovascular diseases is apparent (i.e., ‘confounded’ by air pollution that have not been adjusted for) or that environmental noise is a risk factor for CVD in itself, independent of the effect of air pollution.

In a large cohort study on air pollution, all-cause mortality, and specific morbidity (including cardiovascular diseases) over an 8-year-period, the association between background air pollutant concentrations and mortality decreased and became insignificant, while the distance of the residence from a major road showed a strong and significant association (RR = 1.95; 95% CI: 1.09–3.51) (Hoek et al, 2002). Having already adjusted for other confounders, the authors concluded that the unexpected association could be explained by an unknown confounder, which Babisch (2006) suggested could be road traffic noise. Another possible explanation for the results, in my view, could be that the distance from a major road better reflects the subjects’ true exposure to air pollutants than the estimated background air pollutant levels based on air quality monitoring stations in the area. Hence, the association with health outcomes for ‘distance from a major road’ would be stronger than for background pollutant concentrations.

In a recent study, Beelen et al (2009) investigated the joint effect of air pollution and noise from road traffic on cardiovascular mortality in a Dutch cohort study (on diet and cancer). The correlations between traffic noise and background black smoke, and traffic intensity on the nearest road was only moderate ($r = 0.24$ and 0.30). Traffic intensity was associated with cardiovascular mortality, with the highest RR for IHD (RR = 1.11; 95% CI: 1.03–1.20, for an increment of 10,000 motor vehicles per 24 hours). RR for black smoke was significantly higher for cerebrovascular deaths and heart failure mortality. These RR were insensitive to adjustment for traffic noise. They concluded that traffic-related air pollution was associated with cardiovascular mortality, which was not explained by traffic noise, while the independent contribution of exposure to traffic-related noise on cardiovascular mortality was less clear. The potential confounding effect of air pollution on IHD has been adjusted for in a study of hypertension and road traffic noise exposure (de Kluizenaar, et al, 2007). Before adjustment for confounders, road traffic noise exposure was associated with self-reported use of antihypertensive medication among inhabitants in a large sample in Groningen. After adjustment for PM10, the OR for hypertension became smaller and non-significant. Significantly higher adjusted OR were observed only for subjects between 45 and 55 years (before adjustment, OR=1.31; after adjustment, OR=1.19).

A time series study in Madrid, on air pollution and health, found a significantly higher risk of daily emergency hospital admissions for all causes, circulatory causes, and respiratory causes on days with higher background noise, after controlling for air pollutant effects (Tobias et al, 2001). Babisch (2006) noted, however, that the interpretation of such findings was difficult, because the noise hypothesis assumed that long-term cardiovascular illnesses were related to long-term exposure to noise, rather than to the short-term changes that were usually recorded in a time series study.

There is evidence that the relation between road traffic noise and cardiovascular illnesses is stronger among those who are annoyed by exposure to noise, compared to those who are not. Babisch (2006) quoted examples that included the LARES study of eight European cities (Niemann & Maschke, 2004) and the Spandau health survey (Maschke et al, 2003). The LARES study is limited by the absence of noise estimates or measurements. In the latter, it is possible that noise might have acted as a proxy for traffic exhaust fumes. The pooled estimate of the RRs of IHD in the Caerphilly and Speedwell studies was significant in highly annoyed subjects, and ranged from 1.0 to 1.4 (Babisch et al, 1999 & 2003). There was also effect modification by pre-existing illnesses, with higher RRs among healthy subjects (RR = 1.7–2.7), but not in subjects with chronic diseases.

The NaRoMI case-control study on road traffic noise in Berlin yielded significant RRs while going up the noise annoyance categories (for each category, RR = 1.1 compared to the previous category), but only in men. Annoyance due to aircraft noise at night, however, was significantly associated with MI risk in women (RR = 2.1) but not in men. Annoyance to daytime noise was not associated with MI risk. No plausible explanations for the conflicting results have been proposed in the review by Babisch (2006). Nevertheless, in his latest update, Babisch (2008) performed meta-analyses for two descriptive studies and five analytical (case-control and cohort) studies on road traffic noise and cardiovascular risk. The results yielded a pooled dose-response curve, with an increase in risk at a noise level above 60 dBA. However, the odds ratios for MI for the highest noise exposure group ($L_{DAY,\ 16\ h}$ = 66–70 dBA) were statistically insignificant (OR = 1.14 and 1.19 respectively for the descriptive and analytic studies).

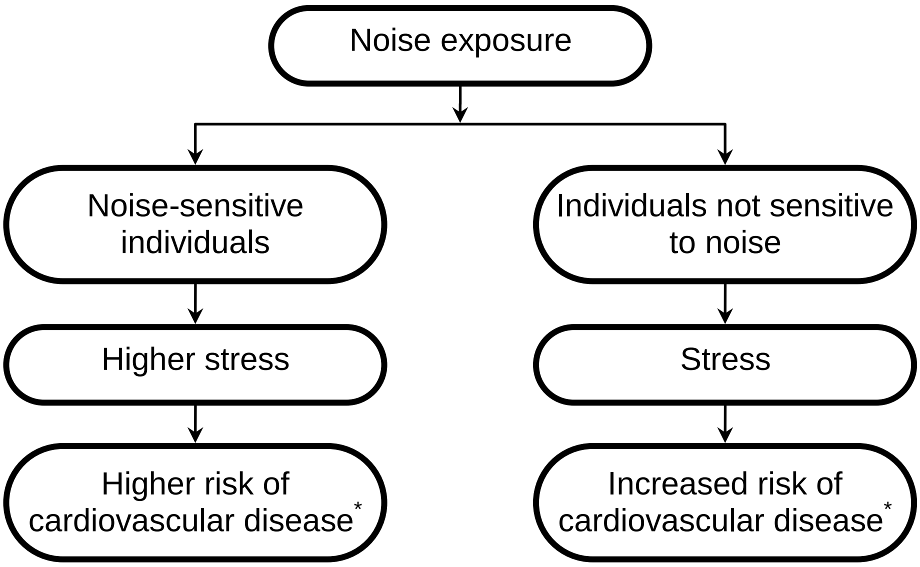
Several other studies used consumption of antihypertensive drugs and other cardiovascular medicines as a proxy for IHD and hypertension. There is some evidence from the Amsterdam airport study (Knipschild, 1977a), the Bonn study (Eiff & Neus, 1980; Eiff et al, 1981; Neus et al, 1983), and the Erfurt study (Schulze et al, 1983), that noise-exposed subjects had a higher use of cardiovascular and other drugs. Although the general direction of the results agrees with the noise and cardiovascular illness hypothesis, the evidence is stronger for other medicines related to sleep disturbance, such as sleeping pills, sedatives, and tranquilisers.

In a recent study (Fyhri & Klæboe, 2009) that explored the relationship between road traffic noise and health, 1,842 respondents in Oslo, Norway were interviewed on subjective health complaints, environmental noise (L_{DEN}), and air pollution (NO_2) using the structural equation model (considered to be a more powerful alternative to multiple regression analysis). While noise sensitivity was found to be associated with hypertension and chest pain, no relationship between noise exposure and health complaints was identified. The authors suggested that the noise-health relationship might be spurious, and that individual vulnerability was reflected both in ill health and sensitivity to noise.

Whether noise annoyance and noise sensitivity are effect modifiers of the relationship between noise and cardiovascular diseases, or are merely outcomes associated with cardiovascular diseases, both due to underlying ill health, has yet to be determined.

3.4 Two hypotheses of environmental noise and cardiovascular disease

(i) Causative role of environmental noise on cardiovascular disease:
The model in Figure 2 demonstrates a hypothesis on noise, reactions to noise, and health. It assumes that noise sensitivity is an effect modifier. On exposure to environmental noise, noise-sensitive subjects bear a higher risk of cardiovascular disease compared to those who are not.



* As compared to the reference group of low-risk individuals who are not exposed

Figure 2: Noise sensitivity as an effect modifier in the noise-stress-illness model

(ii) Environmental noise does not play a causal role on cardiovascular disease:
In epidemiological research, a proposed alternative model for the relationship between noise, reactions to noise, and health assumes that noise sensitivity, annoyance, and cardiovascular disease are all outcomes of underlying ill-health (Fyhri & Klæboe, 2009). The associations of annoyance and noise sensitivity with cardiovascular disease would then be spurious (Figure 3).

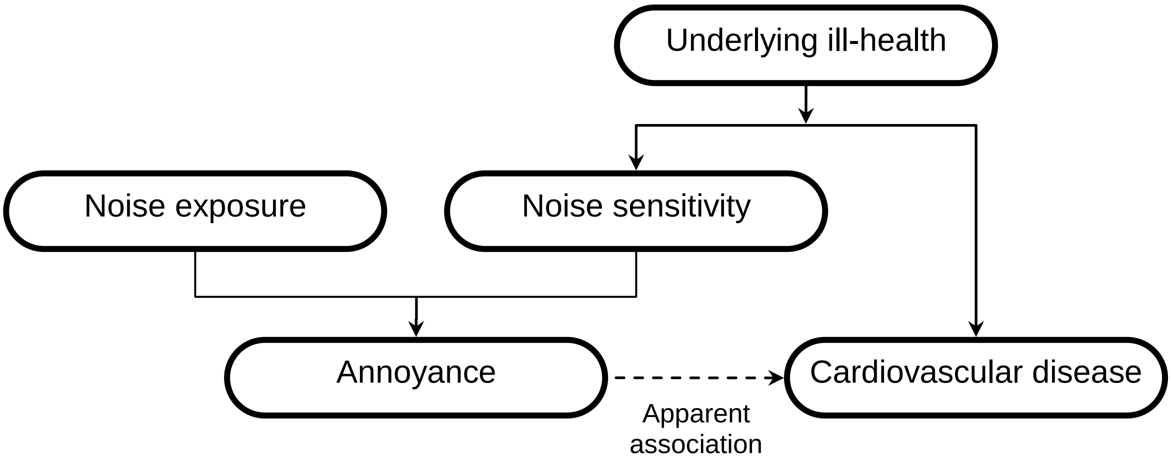


Figure 3: A possibly spurious relationship between annoyance to noise and cardiovascular disease

The association between noise and cardiovascular diseases has been shown to be stronger in those annoyed by noise than in those who are not. This relationship has also been observed among noise-sensitive people. Whether noise annoyance and sensitivity are effect modifiers of a true association between noise and health, or are confounders as shown in Figure 3 above, has not been investigated. Likewise, air pollution is a potential confounder in the noise-cardiovascular disease relationship. Its role as the underlying risk factor that might explain the observed association between environmental noise and cardiovascular disease has not been assessed.

4 Noise exposure-response curves and noise metrics

Babisch (2008) constructed a pooled exposure-response curve by meta-analyses of two descriptive and five analytic studies. No increase in risk was found below 60 dBA for L_{day}, although Babisch claimed a dose-response relationship with increasing noise levels above 60 dBA. He advocated the use of the following polynomial function for the risk assessment and calculation of the disease burden attributed to environmental noise:

$$OR = 1.629657 - 0.000613\,(L_{DAY,\,16h})^2 + 0.000007357\,(L_{DAY,\,16h})^3\ (R^2 = 0.96)$$

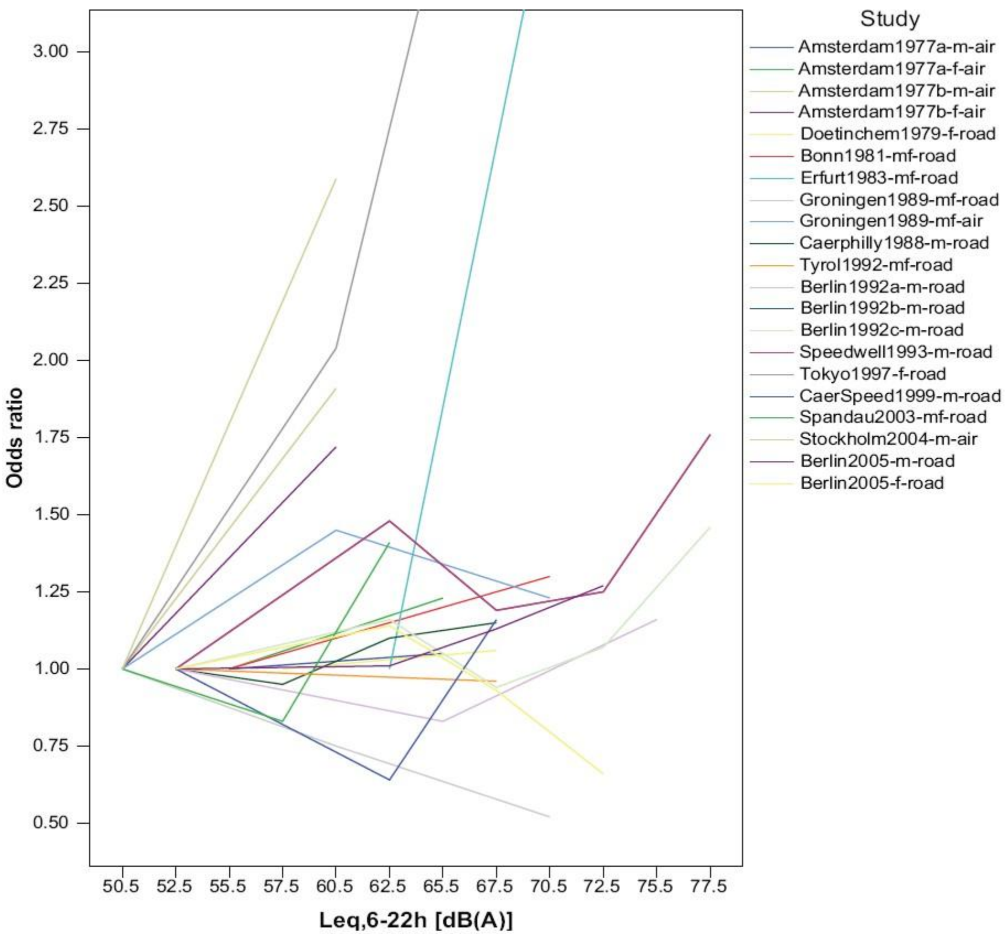
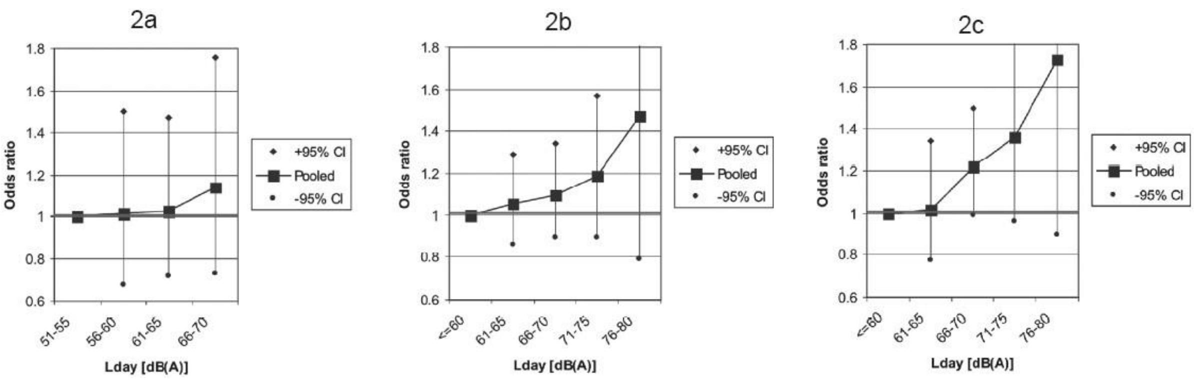


Figure 4: Relative risk of IHD found in environmental noise studies (Source: Babisch, 2008)

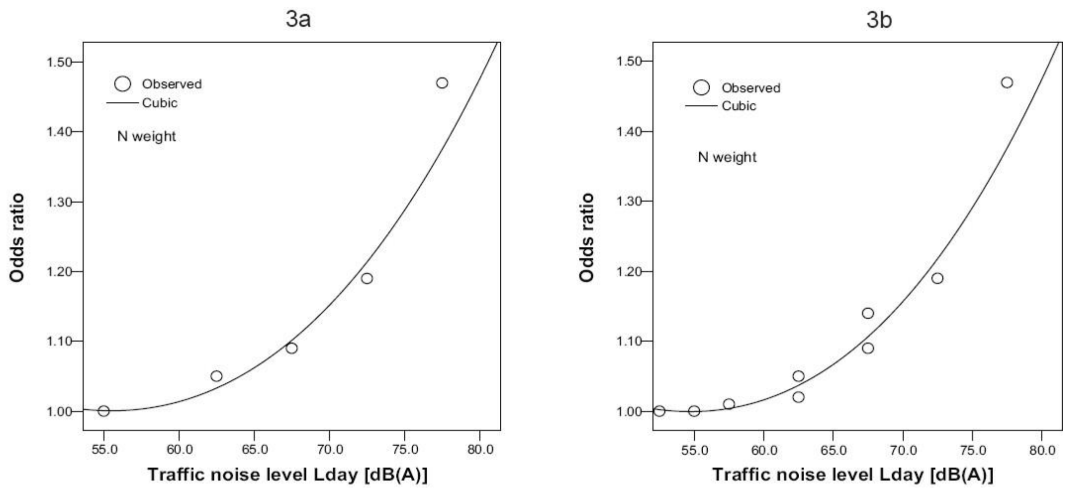


2a Cross-sectional studies

2b Case-control/ cohort studies

2c Sub-samples of case-control and cohort studies with long years of residence

Figure 5: Pooled effect estimates (meta-analysis) of studies on the association between road traffic noise level and myocardial infarction (OR ± 95% confidence interval) (Source: Babisch, 2008)



Case-control/ cohort studies

(*Analytic studies*)

Cross-sectional, case-control, and cohort studies

(*Descriptive and analytic studies*)

Figure 6: Polynomial fits of the exposure-response relationship between road traffic noise and myocardial infarction (Source: Babisch, 2008)

Babisch and Kamp derived an exposure-response relationship between aircraft noise and the risk of hypertension based on meta-analysis (Babisch & Kamp, 2009). The pooled effect estimate from five studies was: OR = 1.13 (95% CI:1.00-1.28) per 10 dB(A) increase of the day/night average weighted sound pressure level of aircraft noise, range = 45-70 dB(A). The authors cautioned, however, that this association must be regarded as preliminary, owing to methodological issues involved in pooled data. The authors concluded that there was sufficient evidence for a positive relationship between aircraft noise and high blood pressure and the use of cardiovascular medication. The RR from the meta-analysis represents a "best guess" estimate that can be used for practical purposes of quantitative risk assessment until more data are available.

There is no universally accepted noise exposure indicator for cardiovascular effects. The HYENA study used those recommended by the WHO (1999): $L_{Aeq\ T}$, being the A-weighted equivalent continuous noise level over T hours. For aircraft noise, the indicators $L_{Aeq\ 16\ h}$ (day being defined as the hours between 0700 and 2300, or between 0600 and 2200 hours, depending on the local definition) and L_{NIGHT} (night being defined as between 2300 and 0700 or between 2200 and 0600 hours) to differentiate between the effects of daytime and night-time exposure. In many countries, only aggregated 24-hour data on road traffic noise are available, and $L_{Aeq\ 24h}$ and L_{NIGHT} are derived from these data.

5 Conclusions

We have reviewed a large number of studies, published between 1980 and 2009, on environmental noise and cardiovascular diseases. While some studies reported fairly consistent findings, others gave insignificant or even contradictory results. Consistency of findings is one of the criteria (though not a 'necessary' criterion) for causation in the determination of a cause-effect relationship, as advocated by Hill (Hill, 1965). Hence, similar results reported by a large number of studies are regarded as being more credible than that reported in a single study. On the contrary, contradictory findings can be interpreted as the absence of consensus in the scientific community. These can arise when the effect size of the risk factor under study is small. A risk factor with a small RR or OR is easily influenced by confounding factors, especially when there are multiple confounding factors that are difficult to identify and control for. Statistically insignificant results can arise when the sample size of the study is too small, or the effect size is too small, or both. The proper interpretation of an insignificant result is that the observed results can be a chance finding. Care must be given in the interpretation of a scientific paper. Besides noting the magnitude of the RR, OR or other risk estimates and their statistically significance at specified levels, other issues in the study design, such as biases in sample selection and ascertainment of 'exposure' and 'effects' must be critically examined. Potential confounding factors must be identified and controlled for, to reduce the likelihood of making an erroneous conclusion.

Environmental noise, whether from transport, industry, or neighbours, has been extensively studied with respect to its effect on cardiovascular health. While acute exposure to noise results in physiological responses, it is uncertain whether such effects are associated with the long-term risk of cardiovascular diseases.

The magnitude of the difference in blood pressure between those exposed to noise and the control group is small and of little clinical significance. Whether hypertension will be a consequence of noise exposure in childhood is still unknown. Adult hypertension might be linked to aircraft noise, as evidenced by a recent cohort study (Eriksson et al, 2007). Evidence for a link between hypertension and road traffic noise has increased from recent studies. Earlier inconsistencies might well be explained by bias, or by inadequate adjustment for confounding factors.

The link between ischaemic heart disease and noise is less convincing, with statistically insignificant and inconsistent findings, even from cohort studies and meta-analyses. The pooled risk estimates are small and insignificant even for the highest noise exposure categories. The role of confounding factors, including air pollution is being investigated.

The link between noise and special groups, such as those annoyed by noise and noise-sensitive individuals, could also be explained by the common factor of underlying ill health; this might account for noise sensitivity that leads to annoyance, and also to cardiovascular diseases. It is therefore prudent to consider the exposure-response relationships as provisional, subject to further studies that can settle the uncertainties, confounding factors, and biases that interfere with the hypothesised relationships on noise, stress, and health.

As a final note, I shall discuss the relevance and applicability of overseas studies on environmental noise and cardiovascular diseases. Physiologically, the response of the human body to external stimuli such as noise is common to all races. However, the magnitude of such response, whether manifested as physiological adaptation or pathological development (leading to diseases), depends on the exposure – the noise level, frequency, duration, and other characteristics of noise, the time of the day (or night), and the recipient himself / herself – the age, the health status, whether the person is noise-sensitive, and other personal factors. Some studies, even done in the same cities, reported different results over time or between different subjects. Thus, one cannot generalize the quantitative exposure-response relationship from overseas studies to the Hong Kong population. Nevertheless, overseas studies are relevant to Hong Kong because a large proportion of our citizens are living in an environment with a moderate to high level of noise, either within our homes or outside. Furthermore, our urban lifestyle, typical of developed cities is associated with a high prevalence of cardiovascular diseases such as hypertension, stroke and ischaemic heart diseases. This literature review is highly relevant to the health of Hong Kong people because many of us are highly exposed to environmental noise, and the 'population attributable risk' is high, even though the RRs or ORs of these diseases attributable to environmental noise may be low. This observation has a practical public health implication: effective measures to reduce environmental noise may lead to a substantial decline in the risk of cardiovascular diseases.

Glossary

A-weighting
A-weighting is a system where sound measurements are weighted, according to the response of the human ear, to sounds of different frequencies. Heavier weighting is given to audio frequencies to which humans are more sensitive, while sounds less readily perceived receive less. The A-weighting curve is generally applied where the human response is of greatest interest, for example in environmental noise measurements. Its use is indicated by the measurement unit, dBA.

Decibel (dB)
A unit of measurement for sound energy or sound pressure level. It is calculated on a logarithmic scale. As a rule of thumb, a 3 dB increase in sound level represents a doubling in the sound energy. Decibels can be expressed following different weighting curves, depending on the purpose of the measurement; see 'A-weighting' for one such example.

Equivalent sound level (L_{eq})
In environmental noise measurements, noise levels fluctuate over time. For the meaningful comparison of noise levels, a summary descriptor called the 'equivalent sound level' (L_{eq}) is often used. The L_{eq} is an averaged measure of the sound level, calculated by dividing the sum of the total sound energy by the total time period of measurement, which is usually quoted. For example, the L_{eq} measured over 24 hours is denoted by $L_{eq\ 24h}$; L_{DAY} (7 am to 10 pm) and L_{NIGHT} (10 pm to 7 am) refer to noise levels measured during their respective time periods. The measures L_{DN} (day and night) and L_{DEN} (day, evening, and night) are forms of $L_{eq\ 24h}$ in which 5 dB are added to noise measurements made in the evening (7 pm to11 pm for L_{DEN}), and 10 dB are added to measurements made at night (defined as 10 pm to 7 am for L_{DN}, and 11 pm to 7 am for L_{DEN}). The L_{Aeq} is the equivalent sound level measured with A-weighting, and is expressed in dBA.

Maximum sound level (L_{max})
The maximum sound level (L_{max}) denotes the peak sound level measured.

Odds ratio (OR)
The 'odds ratio' compares the odds of an event in one group to the odds of an event in another group. In the context of epidemiology, the 'odds' of disease is defined as the number of people with a disease, divided by the number of people without it. The OR is thus the ratio of the odds of disease among an exposed group, to the odds in a non-exposed group. An OR value of 1 means that there is no difference between the two groups; there is no additional risk in exposure. An OR value greater than 1 indicates an increased risk, while a value less than 1 indicates a reduced risk. The OR is obtained from case-control studies.

P-value
The probability, denoted as 'p', that a result has occurred by chance, assuming that the 'null hypothesis' is true. When the value of p is small, the probability that an observation is due to chance is low; therefore the proposed association between cause and effect is more likely to be true (hence the null hypothesis can be rejected). Such a result is said to be 'statistically significant'.

Relative risk (RR)
'Relative risk' is a ratio of the risk of an adverse event in two groups. In epidemiology, the 'risk' of a given disease is equivalent to the 'incidence' of disease; namely, the number of people with the disease, divided by the total population at risk (which includes both healthy and diseased individuals). The relative risk is the ratio of the disease risk among those exposed to a particular risk factor, to the disease risk in those not exposed. An RR value of 1 means that there is no difference between the exposed and non-exposed groups, and that there is no additional risk in exposure. An RR value greater than 1 indicates an increased risk, while a value less than 1 indicates a reduced risk. The RR can be obtained using a 'cohort' or follow-up study.

Statistical significance
A statistically significant result is one that is unlikely to have occurred by chance, and is often expressed in scientific literature by means of a small p-value (conventionally, $p < 0.05$).

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Appendix

Appendix 1: Summary table of original papers on noise and cardiovascular diseases

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
Altena K, Biesiot W, Van Brederode NE, Van Kamp I, Knottnerus TR, Lako JV, Pulles MRJ, Stewart RE, Veldman JBP, eds. *(See also Pulles et al, 1990)*	Environmental noise and health: Description of data, models, methods and results. Report No. GA-DR-03-01 *(Technical report in Dutch)*	Leidschendam : Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (Ministerie van VROM) *(The Hague: Ministry of Housing, Spatial Planning and Environment)*	1988	Traffic & military aircraft noise and ischaemic heart disease & blood pressure	829 adults (males & females, aged 22–55 years)	Aircraft noise >~55 dBA Traffic noise from ~51–75 dBA L_{den} ≤60 vs. >56 dBA	For IHD: Prevalence ratio mainly > 1.0; range = 0.77–1.48 (but none are significant) Prevalence ratio mainly < 1.0; range = 0.52–1.03 (but none are significant) For blood pressure: Difference in mean systolic BP = -1 to +5 mmHg (significant; p<0.05) Difference in mean diastolic BP = -1 to +2 mmHg (not significant)	Four cities in the Netherlands: Groningen, Twenthe, Leeuwarden, Amsterdam Cross-sectional study No dose-response relationship found for IHD and aircraft or traffic noise No clear pattern observed for noise and blood pressure

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
Babisch W, Beule B, Schust M, Kersten N, Ising H	Traffic noise and risk of myocardial infarction	Epidemiology; 16:33-40	2005	Traffic noise and myocardial infarction	4,115 patients (3,054 men & 1,061 women) from 32 hospitals	$L_{DAY, 6\text{-}22\ h}$ >70 dBA (highest noise levels)	OR = 1.27 for men (not significant) OR = 1.81 for men living at current address for ≥ 10 years (significant)	Berlin, Germany Part of the 'Noise and Risk of Myocardial Infarction' (NaRoMI) study No increase in cardiovascular risk up to L_{DAY} = 60 dB; dose-response relationship for L_{DAY} < 60–75 dBA
Babisch W, Gallacher JE, Elwood PC, Ising H *(See also Babisch et al, 1993b)*	Traffic noise and cardiovascular risk. The Caerphilly study, first phase. Outdoor noise levels and risk factors	Arch Environ Health; 43(6):407-14	1988	Traffic noise and ischaemic heart disease & hypertension	2,512 adult males (aged 45–59)	L_{DAY}: 51–55 dBA vs. 66–70 dBA	For blood pressure: Difference in mean systolic BP = 1 mmHg (not significant) Difference in mean diastolic BP = -1 mmHg (not significant) For angina pectoris:	Caerphilly, South Wales, UK Cross-sectional study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
							RR = 0.52 (not significant; 95% CI: 0.19–1.44) For myocardial infarction: RR = 1.22 (not significant; 95% CI: 0.63–2.33) For ischaemic heart disease RR = 1.15 (not significant; 95% CI: 0.67–1.96)	
Babisch W, Ising H, Gallacher JE, Sharp DS, Baker IA *(See also Babisch et al, 1993b)*	Traffic noise and cardiovascular risk: The Speedwell study, first phase. Outdoor noise level and risk factors	Arch Environ Health; 48:401-5	1993a	Traffic noise and ischaemic heart disease & hypertension	2,348 adult males (aged 45–63)	L_{DAY}: 51–55 dBA vs. 66–70 dBA	For blood pressure: Difference in mean systolic BP = -3 mmHg (not significant) Difference in mean diastolic BP = -1 mmHg (significant; p<0.05) For angina pectoris:	Speedwell, England, UK Cross-sectional study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
							RR = 1.10 (not significant; 95% CI: 0.65–1.87) For myocardial infarction: RR = 1.07 (not significant; 95% CI: 0.59–1.93) For ischaemic heart disease RR = 1.25 (not significant; 95% CI: 0.82–1.89)	
Babisch W, Ising H, Elwood PC, Sharp DS, Bainton D *(See also Babisch et al, 1988; Babisch et al, 1993a)*	Traffic noise and cardiovascular risk: The Caerphilly and Speedwell studies, second phase. Risk estimation, prevalence and incidence of ischaemic heart disease	Arch Environ Health; 48:406-13	1993b	Traffic noise and ischaemic heart disease	4,860 adult males (aged 45–63) in 2 cohorts: 2,512 men in Caerphilly; 2,348 men in Speedwell	Highest noise group: $L_{eq\ 6\text{-}22h}$ = 66–70 dBA (As compared to lowest noise group, $L_{eq\ 6\text{-}22h}$ = 51–55 dBA)	IHD incidence: RR = 1.1 IHD prevalence: RR = 1.2	Caerphilly, South Wales and Speedwell, England, UK Cross-sectional study
Babisch W, Ising H, Gallacher JE, Sweetnam PM,	Traffic noise and cardiovascular risk: The	Arch Environ Health; 54:210-6	1999	Traffic noise and ischaemic	4,860 adult males (aged 45–	L_{eq} = 51–70 dBA (6–22 hours chronic	Caerphilly cohort: OR = 1.1	Caerphilly, South Wales and Speedwell,

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
Elwood PC	Caerphilly and Speedwell studies, third phase – 10 years follow-up			heart disease	63) in 2 cohorts: 2,512 men in Caerphilly; 2,348 men in Speedwell	noise exposure) ORs & RRs quoted are for highest traffic noise areas (66–70 dBA) compared to lowest (51–55 dBA) L_{DAY} = 51–70 dBA L_{DAY} = 66–70 dBA	(adjusted; not significant) Speedwell cohort: OR = 0.9 (adjusted; not significant) Follow-up: RRs = 1.2–1.6 (not significant) RR = 1.01 – 1.02 per year of exposure	England, UK Prospective study following 2 cohorts of men Initial data does not indicate that traffic noise level increases risk for IHD – outdoor, address-related noise levels might not be high enough to observe effect Analysis of 6-year follow-up (with additional information on environment and subjects that affect exposure) gave raised RRs (not significant, except in a pool of highly annoyed subjects)

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
Babisch W, Ising H, Kruppa B, Wiens D *(See also Babisch et al, 1994)*	Verkehrslärm und Herzinfarkt, Ergebnisse zweier Fall-Kontroll-Studien in Berlin	WaBoLu-Hefte 2/92, Berlin, Institut fur Wasser-, Boden- und Lufthygiene, Umweltbundes amt	1992	Traffic noise and myocardial infarction	243 adult males (aged 41–70 years)	L_{DAY} = 66–70 dBA L_{DAY} = 76–80 dBA	RR = 1.19 (not significant; 95% CI: 0.49–2.86) RR = 1.76 (not significant; 95% CI: 0.11–28.8)	Berlin, Germany Prospective case-control study Increased risk for subjects with ≥ 15 years of exposure
Babisch W, Ising H, Kruppa B, Wiens D *(See also Babisch, et al, 1992)*	The incidence of myocardial infarction and its relation to road traffic noise – the Berlin case-control studies	Environ Int; 20:469-74	1994	Traffic noise and myocardial infarction	243 adult males (aged 41–70 years)	L_{DAY} = 66–70 dBA L_{DAY} = 76–80 dBA	RR = 1.19 (not significant; 95% CI: 0.49–2.86) RR = 1.76 (not significant; 95% CI: 0.11–28.8)	Berlin, Germany Prospective case-control study Increased risk for subjects with ≥ 15 years of exposure
Barregard L, Bonde E, Ohrstrom E	Risk of hypertension from exposure to road traffic noise in a population-based sample	Occup Environ Med; 66:410-5	2009	Traffic & railway noise and hypertension	1,953 adults (aged 18–75)	$L_{Aeq,\,24h}$ = 56–70 dBA	OR = 1.9 (significant)	Lerum, Sweden Postal questionnaire survey Showed exposure-response relationship Strengths: High

Author(s)	**Title**	**Publication / Publisher**	**Year**	**Area of Study**	**Subjects**	**Noise Levels / Classifications**	**Results**	**Remarks**
								response rate (71%)
Beelen R, Hoek G, Houthuijs D, van den Brandt PA, Goldbohm RA, Fischer P, Schouten LJ, Armstrong B, Brunekreef B	The joint association of air pollution and noise from road traffic with cardiovascular mortality in a cohort study	Occup Environ Med; 66(4):243-250	2009	Traffic noise & air pollution and cardiovascula r mortality	120,852 adults (aged 55–69 years)	 Traffic noise exposure (>65 dBA) only Traffic noise exposure (>65 dBA) after adjusting for air pollution indicators	For overall cardiovascular mortality: RR = 1.25 (significant; 95% CI: 1.01–1.53) RR = 1.17 (not significant; 95% CI: 0.94–1.45)	The Netherlands Cohort study RRs for cardiovascular mortality and traffic noise were not significant after adjustment for air pollution indicators (background black smoke, traffic intensity). Conversely, air pollution RRs were not sensitive to adjustment for traffic noise
Bellach B, Dortschy R, Müller D, Ziese T *(See also Müller et al, 1994)*	Gesundheitliche Auswirkungen von Larmbelastung – Methodische Betrachtungen zu den Ergebnissen	Bundesgesund hbl; 38:84-9	1995	Traffic noise and hypertension	1,002 adults (males & females, aged 40–65 years)	Annoyance at traffic noise	RR = 0.92 with ‘global’ disturbance RR = 2.32 with reported sleep disturbance	Germany General population follow-up study / Cross-sectional study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
	dreier epidemiologische r Studien						(significant)	
Belojevic G, Saric-Tanaskovic M	Prevalence of arterial hypertension and myocardial infarction in relation to subjective ratings of traffic noise exposure	Noise & Health; 4(16):33-37	2002	Traffic noise and hypertension & myocardial infarction	2,874 adults (1,243 men and 1,631 women)	Noise annoyance ratings: High vs. low ('Low' annoyance ratings used as the reference category)	For arterial hypertension: Adjusted OR = 1.8 in males (significant; 95%CI: 1.0–2.4) Adjusted OR = 1.1 in females (not significant; 95%CI: 0.8–1.7) For myocardial infarction: Adjusted OR = 1.7 in males (significant; 95%CI: 1.0–2.9) Adjusted OR = 1.0 in females (not significant; 95%CI: 0.4–2.0)	Pancevo, Serbia Cross-sectional study
Bluhm G, Rosenlund M,	Traffic noise and health effects. In:	National Capital	1998	Traffic noise and	759 adults (males &	$L_{eq\ 24h}$ >50 dBA (exposed)	Overall RR for hypertension =	Sollentuna, Sweden

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
Berglind N	Carter N, Job RF, eds. Noise Effects ’98. Proceedings of the 7th International Congress on Noise as a Public Health Problem, Sydney, Vol. 1; p247-50.	Printing Act: Sydney		hypertension	females, aged 19–80 years)	40–65 dBA (road traffic noise) 55–65 dBA (train noise)	1.5 (not significant) RR = 2.4 for long-term residents (≥10 years); significant RR = 1.8 (road traffic noise; significant) RR = 0.8 (train noise; not significant)	Cross-sectional study
Bluhm G, Erikkson C, Hilding A, Östenson CG	Aircraft noise exposure and cardiovascular risk among men – First results from a study around Stockholm-Arlanda Airport	Czech Acoustical Society. Proceedings of the 33rd International Congress and Exhibition on Noise Control Engineering. The Czech Acoustical Society:	2004	Aircraft noise and cardiovascula r risk	417 adult males (aged 45–65 years)	>55 dBA	For myocardial infarction: RR = 2.6 For angina pectoris: RR = 0.9	Stockholm, Sweden

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
		Prague						
Bodin T, Albin M, Ardö J, Stroh E, Östergren PO, Björk J	Road traffic noise and hypertension: results from a cross-sectional public health survey in southern Sweden	Environ Health; 8(38) Available at: http://www.ehjournal.net/content/8/1/38	2009	Traffic noise and hypertension	24,238 adults (aged 18-80 years)	$L_{Aeq\ 24\ h}$ (per 10 dBA increase) 45–64 dBA >64 dBA	OR =1.06 OR = 1.1 (not significant) OR = 1.45 (significant)	Southern Sweden Cross-sectional study Weaknesses: Hypertension was self-reported, may have been under-reported; not adjusted for air pollution
Cohen S, Evans GW, Krantz D, Stokols D *(See also Cohen et al, 1981)*	Physiological, motivational and cognitive effects of aircraft noise on children: Moving from the laboratory to the field	Am Psychol; 35:231-43	1980	Aircraft noise and blood pressure	262 primary school children (males & females, aged around 8–10 years)	$L_{max,\ mean}$ indoor: 56 dBA vs. 74 dBA	Difference in mean systolic BP = +3 to +7 mmHg (significant; p<0.05) Difference in mean diastolic BP = +3 to +4 mmHg (not significant; p<0.10)	Los Angeles, CA, USA Cross-sectional study Small differences in blood pressure observed between different exposure groups Decreasing BP trend with increasing years of enrolment at

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
								school
Cohen S, Evans GW, Krantz D, Stokols D, Sheryl K *(See also Cohen et al, 1980)*	Aircraft noise and children: Longitudinal and cross-sectional evidence on adaptation to noise and the effectiveness of noise abatement	J Personality Soc Psychol; 40:331-45	1981	Aircraft noise and blood pressure	163 primary school children (males & females, aged around 8–10 years)	$L_{max, mean}$ indoor: 57 dBA vs. 79 dBA	Difference in mean systolic BP = -2 to +7 mmHg (not significant) Difference in mean diastolic BP = +1 to +7 mmHg (not significant)	Los Angeles, CA, USA Prospective cohort study – 1 year follow-up to above study Small differences in blood pressure observed between different exposure groups; not significant
Eiff AW, Czernik A, Horbach L, Jörgens H, Wenig HG *(See also Rohrmann, 1974)*	Kapitel 7: Der medizinische Untersuchungstei l	Forschungsge meinschaft D, ed. Fluglärmwirku ngen I, Hauptbericht. Herald Boldt Verlag KG: Boppard; p349-424.	1974	Aircraft noise and blood pressure	392 adults (males & females, aged 21–60 years)	$L_{max,mean}$: <87 dBA vs. >95 dBA	Difference in mean systolic BP = 2 mmHg Difference in mean diastolic BP = 3 mmHg	Munich, Germany Cross-sectional study BP differences not significant
Eiff AW, Neus H *(See also Eiff et al, 1981; Neus et al,*	Verkehrslärm und Hypertonie-Risiko. 1. Mitteilung: Verkehrslärm	Münch Med Wochenschr; 122:893-6	1980	Traffic noise and hypertension, blood pressure &	931 adults (males & females, aged 20–59 years)	L_{DAY}: <60 dBA vs. >65 dBA	Difference in mean systolic BP = 1 mmHg (not significant)	Bonn, Germany Cross-sectional study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
1983)	und Hypertonie-Risiko			myocardial infarction			Difference in mean diastolic BP = 1 mmHg (not significant) For hypertension: RR = 1.52 (significant; 95% CI: 1.02–1.15) For myocardial infarction: RR = 1.30 (not significant; 95% CI: 0.44–3.56)	
Eiff AW, Neus H, Friedrich G, Langewitz W, Rüddel H, Schirmer G, et al *(See also Eiff and Neus, 1980; Neus et al, 1983)*	Feststellung der erheblichen Belästigung durch Verkehrslärm mit Mitteln der Streßforschung (Bonner Verkehrslärmstudie)	Umweltforschungsplan des Bundesminister des Innern, Lärmbekämpfung, Forschungsberichts. Nr. 81-10501303. Umweltbundesamt: Berlin	1981	Traffic noise and hypertension, blood pressure & myocardial infarction	931 adults (males & females, aged 20–59 years)	L_{DAY}: <60 dBA vs. >65 dBA	Difference in mean systolic BP = 1 mmHg (not significant) Difference in mean diastolic BP = 1 mmHg (not significant) For hypertension: RR = 1.52	Bonn, Germany Cross-sectional study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
							(significant; 95% CI: 1.02–1.15) For myocardial infarction: RR = 1.30 (not significant; 95% CI: 0.44–3.56)	
Eriksson C, Rosenlund M, Pershagen G, Hilding A, Östenson C-G, Bluhm G	Aircraft noise and incidence of hypertension	Epidemiology; 18(6):716-721	2007	Aircraft noise and hypertension	2,754 middle-aged men studied (2,027 men analysed); resident around Stockholm Arlanda Airport	$L_{Aeq, 24h}$ >50 dBA (energy-averaged levels) $L_{Aeq, 24h}$ >70 dBA (maximum levels)	Adjusted RR = 1.19 Adjusted RR = 1.2 Statistically significant	Stockholm, Sweden Cohort study Stronger association among older subjects Evidence of exposure-response relationship Strengths: Longitudinal design, objective assessment of exposure and outcome, many

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								potential confounding factors adjusted
Evans GW, Bullinger M, Hygge S	Chronic noise exposure and physiological response: A prospective study of children living under environmental stress	Psychol Sci; 9:75-7	1998	Aircraft noise and blood pressure	217 children (mean age 9.9 years) near (exposed) or around (controls) a new airport	$L_{Aeq,\ 24h}$	Mean / SD values shown for blood pressure & neuroendocrine concentrations in urine	Munich, Germany Cohort study / community trial Blood pressure and other stress measures increased in the exposed subjects after opening of new airport; much smaller changes found in controls
Evans GW, Hygge S, Bullinger M	Chronic noise and psychological stress	Psychol Sci; 6:333-8.	1995	Aircraft noise and blood pressure	135 primary school children (males & females, aged around 8–10 years)	$L_{eq\ 24h}$: 59 dBA (lower exposure) vs. 68 dBA (higher exposure)	Difference in mean systolic BP = 2 mmHg ($p<0.10$) Difference in mean diastolic BP = 0 mmHg (not significant)	Munich, Germany Cross-sectional study Difference of 2 mmHg in systolic blood pressure; no difference in

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
								diastolic pressure
Evans GW, Lercher P, Meis M, Ising H, Kofler WW *(See also Lercher et al, 2002)*	Community noise exposure and stress in children	J Acoust Soc Am; 109:1023-7	2001	Traffic & railway noise and blood pressure	115 primary school children (males & females, aged around 9–10 years)	L_{DN}: <50 dBA (lower exposure) vs. >60 dBA (higher exposure)	Difference in mean systolic BP = 2 mmHg (p<0.10) Difference in mean diastolic BP = 0 mmHg (not significant)	Inn Valley, Tyrol, Austria Cross-sectional study Systolic blood pressure marginally higher in children exposed to higher noise levels than those less exposed
Franssen EAM, van Wiechen CMAG, Nagelkerke NJD, Lebret E	Aircraft noise around a large international airport and its impact on general health and medication use	Occup Environ Med; 61:405-13	2004	Aircraft noise and blood pressure, hypertension & CVD	11,812 adults living within 25 km of airport	Per 10 dBA increase in L_{den}	Adjusted OR range: 1.02 to 2.34	Amsterdam, the Netherlands Statistically significant results Weakness: Self-reported health indicators
Goto K, Kaneko T	Distribution of blood pressure data from people living near an airport	J Sound Vibration; 250:145-9	2002	Aircraft noise and blood pressure	1,646 women (469 women living near the airport;	L_{DN} < 60 dBA (reference) $L_{DN} \geq$ 70 dBA (exposed)	Systolic BP higher in exposed group by 4 mmHg Diastolic BP	Fukuoka, Japan Higher systolic BP in exposed group was found in initial study

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					1,177 women living in the suburbs)		lower in exposed group by 4 mmHg	but not in follow-up No obvious difference between the groups
Grazuleviciene R, Lekaviciute J, Mozgeris G, Merkevicius S, Deikus J	Traffic noise emissions and myocardial infarction risk	Polish J Environ Studies; 13(6):737-41	2004	Traffic noise and myocardial infarction	518 adult males (aged 25–64)	L_{DAY} = 60–64 dBA L_{DAY} = 65–69 dBA $L_{DAY} \geq$ 70 dBA L_{DAY} = 60–64 dBA L_{DAY} = 65–69 dBA $L_{DAY} \geq$ 70 dBA	All ages: RR = 1.07 (not significant; 95% CI: 0.88–1.30) RR = 1.31 (significant; 95% CI: 1.02–1.67) RR = 1.33 (not significant; 95% CI: 0.76–2.32) Ages 55–64 years: RR = 1.05 (not significant; 95% CI: 0.80–1.38) RR = 1.18 (not significant; 95% CI: 0.84–1.65) RR = 1.93 (significant; 95% CI: 1.00–	Lithuania Ecological study MI incidence (adjusted for age) per 1,000 increased with increasing noise exposure

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
							3.67)	
Haralabidis AS, Dimakopoulou K, Vigna-Taglianti F, Giampaolo M, Borgini A, Dudley ML, Pershagen G, Bluhm G, Houthuijs D, Babisch W, Velonakis M, Katsouyanni K, Jarup L	Acute effects of night-time noise exposure on blood pressure in populations living near airports	Eur Heart J; 29:658-64	2008	Aircraft noise and blood pressure	140 adults (aged 45–70 years) living near airports	During a15-min interval of an aircraft event	6.2 mmHg increase in systolic BP (significant) 7.4 mmHg increase in diastolic BP (significant)	Europe: Athens, Greece; Milan, Italy; Stockholm, Sweden; London, UK
Heinonen-Guzejev M, Vuorinen HS, Mussalo-Rauhamaa H, et al	The association of noise sensitivity with coronary heart and cardiovascular mortality among Finnish adults	Sci Total Environ; 372(2-3): 406-12	2007	Noise sensitivity and cardiovascular mortality	1,495 adults (688 men, 807 women, aged 31–88 years)	Noise-sensitive individuals	For women: Hazard ratio = 1.80 (significant; 95%CI: 1.07–3.04) For men: Hazard ratio = 0.80 (not significant; 95%CI: 0.45–1.43)	Finland Cohort study, based on the Finnish Twin Cohort
Herbold M, Hense HW, Keil U	Effects of road traffic noise on prevalence of hypertension in	Soz Praeventiv Med; 34:19-23	1989	Traffic noise and blood pressure & hypertension	2,359 adults (males & females,	L_{DAY}: ≤60 dBA (lower exposure) vs. >65 dBA	Difference in mean systolic BP = -1 to +1 mmHg (not	Lübeck, Germany Cross-sectional

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
	men: Results of the Lübeck blood pressure study				aged 30–69 years)	(higher exposure)	significant) Difference in mean diastolic BP = -1 to +2 mmHg ($p<0.10$)	study Non-linear association between BP and noise level across different categories Increase of 2 mmHg in diastolic BP in men exposed to high traffic noise levels; not found in women
Ising H, Rebentisch E, Poustka F, Curio I	Annoyance and health risk caused by military low-altitude flight noise	Int Arch Occup Environ Health; 62:357-63	1990	Military / low-flying aircraft noise and blood pressure & heart rate	94 children (males & females, aged 9–13 years)	150 m area vs. 75 m area ('75 m areas' are considered extreme low-flying areas, where L_{max} = 125 dBA)	Difference in mean systolic BP = -1 mmHg (not significant) Difference in mean diastolic BP = -1 mmHg (not significant)	Münsterland, Germany Cross-sectional study In pre-study, noise from low-flying military aircraft associated with higher systolic BP of up to 9

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
								mmHg in girls, but not in boys. However, not confirmed in this, the main study
Jarup L, Babisch W, Houthuijs D, Pershagen G, Katsouyanni K, Cadum E, Dudley ML, Savigny P, Seiffert I, Swart W, Breugelmans O, Bluhm G, Selander J, Haralabidis A, Dimakopoulou K, Sourtzi P, Velonakis M, Vigna-Taglianti F	Hypertension and exposure to noise near airports: the HYENA study	Environ Health Perspect; 116(3):329-333	2008	Aircraft & traffic noise and hypertension	6,000 adults	Aircraft noise: L_{NIGHT} (per 10 dB increase) Traffic noise: $L_{Aeq,\ 24h}$ (per 10 dB increase)	OR = 1.141 (significant) OR = 1.097 (significant)	Areas near 6 major European airports: Germany (Berlin Tegel), Greece (Athens), Italy (Milano Malpensa), the Netherlands (Amsterdam Schiphol), Sweden (Stockholm Arlanda) and the UK (London Heathrow) Cross-sectional study Weaknesses: Low response rates in some countries; air pollutants not

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								controlled as confounders
Karsdorf G, Klappach H	Einflüsse des Verkehrslärms auf Gesundheit und Leisting bei Oberschülern einer Großstadt	Z Gesamte Hyg; 14:52-4	1968	Traffic noise and blood pressure	269 children of high school age	$L_{phon,\ mean}$ indoor: quiet / least exposed vs. most exposed (70 dB)	Difference in mean systolic BP = +9 to +16 mmHg Difference in mean diastolic BP = +12 to +16 mmHg	Halle, Germany Cross-sectional study Blood pressure increase of over 10 mmHg found in group with highest exposure Exposure-effect relationship
de Kluizenaar Y, Gansevoort RT, Miedema HME, de Jong PE	Hypertension and road traffic noise exposure	J Occup Environ Med; 49(5):484-492	2007	Traffic noise and hypertension	40,856 adults (aged 28–75 years) in cross-sectional analysis 8,592 adults in cohort	L_{den} < 55 dBA	Per 10dB increase in L_{den} OR = 1.35 (unadjusted) (significant; 95% CI: 1.11–1.65) OR = 1.01 (adjusted for PM_{10}) (not significant; 95% CI: 0.76–1.34) OR = 1.24	Groningen, the Netherlands Cross-sectional / cohort study Traffic noise exposure associated with use of antihypertensive medication only before adjustment for PM_{10}

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
						L_{den} ≥ 55 dBA Subjects aged 45–55 years	(unadjusted) (significant; 95% CI: 1.02–1.52) OR = 1.20 (adjusted for PM_{10}) (not significant; 95% CI: 0.81–1.77) OR = 1.24 (unadjusted) (significant; 95% CI: 1.08–1.42) OR = 1.39 (adjusted for PM_{10}) (significant; 95% CI: 1.08–1.77)	OR for hypertension decreased and was not significant after adjustment for PM_{10} (except for subjects aged 45–55 years)
Knipschild P	V. Medical effects of aircraft noise: Community cardiovascular survey	Int Arch Occup Environ Hlth; 40:185-90	1977	Aircraft noise and cardiovascular problems (including angina & hypertension)	5,828 adults (males & females, aged 35–64 years)	 Less noise: B = 20–40 (NNI>37)	Percentage of participants with cardiovascular problems: For angina pectoris: 2.8% For high blood	Haarlemmermeer, the Netherlands (near Amsterdam's Schiphol Airport) Cross-sectional study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
						Much noise: B = 40–60 (NNI = 20–37) $L_{Aeq,\ 7–19\ h}$ = 55–72 dBA (approximate)	pressure: 3.9% For angina pectoris: 3.0% For high blood pressure: 6.7% Estimated RR per 5 dBA noise increase: For clinical hypertension (male & female): RR = 1.73 (significant; 95% CI: 1.38–2.16) For hypertension (male & female): RR = 1.47 (significant; 95% CI: 1.24–1.73)	Difference in prevalence of cardiovascular troubles was significant for high blood pressure and use of medication / treatment, but not for angina pectoris or pathological EGG
Knipschild P	VI. Medical effects of aircraft	Int Arch Occup Environ	1977	Aircraft noise and GP	18,025 adults	Approximately >60 dBA	For cardiovascular	Amsterdam, the Netherlands

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
	noise: General practice survey	Hlth; 40:191-6		contact rate for cardiovascula r diseases	(males & females, aged 15–64 years)	(outdoor noise)	diseases (male & female): RR = 1.80 (significant; 95% CI: 1.25–2.59)	Survey
Knipschild P	VII. Medical effects of aircraft noise: Drug survey	Int Arch Occup Environ Hlth; 40:197-200	1977	Aircraft noise and cardiovascula r diseases	Pharmacie s (8 years' trend)	Noise levels >65 dBA	RR for demand of antihypertensiv e drugs = 5.5 RR for demand of cardiovascular drugs = 2.4	Amsterdam, the Netherlands Temporal panel ecological study Cardiovascular diseases inferred from the purchase of antihypertensive and cardiovascular drugs by pharmacies Affected by change in population size
Knipschild P, Sallé H	Road traffic noise and cardiovascular disease: A	Int Arch Occup Environ Hlth; 44:55-9	1979	Traffic noise and ischaemic heart disease	1,741 adult females (housewiv es, aged	L_{DN} > 62.5 dBA, 'noisy' (compared to	For ECG abnormalities: RR = 1.1 (not significant)	Doetinchem, the Netherlands Cross-sectional

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
	population study in the Netherlands				40–49 years)	L_{DN} < 62.5 dBA, 'quiet')	For angina: RR = 0.7 (not significant)	study
Lercher P *(See also Lercher & Kofler, 1995)*	Auswirkungen des straßenverkehrs auf Lebensqualität und Gesundheit	Transitverkehrs-Studie, Teil I, Innsbruck, Amt der Tiroler Landesregierung, Landesbaudirektion, Landessanitätsabteilung:1992	1992a	Traffic noise and blood pressure, hypertension, angina pectoris & myocardial infarction	1,989 adults (males & females, aged 25–65 years)	L_{24h}: <50 dBA vs. ≥64 dBA (annoyance) L_{24h}: <50 dBA vs. ≥64 dBA L_{24h}: <55 dBA vs. ≥64 dBA	For blood pressure: Difference in mean systolic BP = -5 to -3 mmHg (significant; p<0.06) Difference in mean diastolic BP = -3 to -1 mmHg (significant; p<0.06) For hypertension: RR = 0.83 (not significant; 95% CI: 0.64–1.10) For angina pectoris: RR = 2.13 (significant; 95% CI: 1.23–	5 villages in Tyrol, Austria Cross-sectional study Significant RR for angina pectoris, but not for myocardial infarction

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
						L_{24h}: <55 dBA vs. ≥64 dBA	3.69) For myocardial infarction: RR = 0.77 (not significant; 95% CI: 0.37–1.62)	
Lercher P	Auswirkungen des straßenverkehrs auf Lebensqualität und Gesundheit	Transitverkehrs-Studie, Teil II, Innsbruck, Amt der Tiroler Landesregierung, Landesbaudirektion, Landessanitätsabteilung:1992	1992b	Traffic noise and blood pressure	796 children (males & females, aged 8–12 years)	L_{24h}: <50 dBA vs. ≥64 dBA	Difference in mean systolic BP = -2 mmHg (not significant) Difference in mean diastolic BP = -2 mmHg (not significant)	7 'noise-exposed' and 6 'control' villages in Tyrol, Austria Cross-sectional study Low increase in blood pressure found in noise-exposed children; non-significant
Lercher P, Evans GW, Meis M, Kofler WW *(See also Evans et al, 2001)*	Ambient neighbourhood noise and children's mental health	Occup Environ Med; 59:380-386	2002	Traffic & railway noise and blood pressure	115 primary school children (males & females, aged	L_{DN}: <50 dBA (lower exposure) vs. >60 dBA (higher exposure)	Difference in mean systolic BP = 2 mmHg (p<0.10) Difference in mean diastolic	Inn Valley, Tyrol, Austria Cross-sectional study Systolic blood

Author(s)	**Title**	**Publication / Publisher**	**Year**	**Area of Study**	**Subjects**	**Noise Levels / Classifications**	**Results**	**Remarks**
					around 9–10 years)		BP = 0 mmHg (not significant)	pressure marginally higher in children exposed to higher noise levels than those less exposed
Lercher P, Kofler WW *(See also Lercher, 1992a)*	Komplexe Antworten auf Umweltbelastungen am Beispiel der Össterreichischen Transitverkehrsstudie	Bundesgesundhbl; 38:95-101.	1995	Traffic noise and ischaemic heart disease	1,989 adults (males & females, aged 25–65 years)	L_{24h}: <50 dBA vs. ≥64 dBA (annoyance) L_{24h}: <50 dBA vs. ≥64 dBA	For blood pressure: Difference in mean systolic BP = -5 to -3 mmHg (significant; p<0.06) Difference in mean diastolic BP = -3 to -1 mmHg (significant; p<0.06) For hypertension: RR = 0.83 (not significant; 95% CI: 0.64–1.10) For angina pectoris:	5 villages in Tyrol, Austria Cross-sectional study Significant RR for angina pectoris, but not for myocardial infarction

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
						L_{24h}: <55 dBA vs. ≥64 dBA L_{24h}: <55 dBA vs. ≥64 dBA	RR = 2.13 (significant; 95% CI: 1.23–3.69) For myocardial infarction: RR = 0.77 (not significant; 95% CI: 0.37–1.62)	
Maschke C, Wolf U, Leitmann T	Epidemiological examinations of the influence of noise stress on the immune system and the emergence of arteriosclerosis	Report 298 62 515 (in German, executive summary in English), WaBoLu-Hefte 01/03. Umweltbundes amt: Berlin, 2003.	2003	Traffic & aircraft noise and hypertension, angina pectoris & myocardial infarction	1,718 adults (males & females, aged 16–90 years)	For hypertension: L_{DAY} >65 dBA L_{NIGHT} > 55 dBA For angina: $L_{eq(4)}$ > 62 dBA For myocardial infarction: $L_{eq(4)}$ > 62 dBA	For hypertension: RR = 1.5 RR = 1.9 For angina: RR = 1.6 (not significant) For myocardial infarction: RR = 0.4	Spandau, Berlin, Germany Cross-sectional study Increased prevalence of hypertension with increased noise exposure, especially at night (significant)
Matsui T, Uehara	The Okinawa	J Sound	2004	Aircraft noise	29,000	L_{DN} = 60–65 dB	Hypertension:	Okinawa, Japan

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
T, Miyakita T, Hiramatsu K, Osada Y, Yamamoto T	study: Effects of chronic aircraft noise on blood pressure and some other physiological indices	Vibration; 277:469-470		and hypertension & blood pressure	residents living around military airfields	(lowest exposure group) L_{DN} > 70 dB (highest exposure group)	OR = 1.4 for most exposed group (compared to reference)	Dose-response relationship between blood pressure and noise exposure; highly significant (p = 0.0002) Reduced lipid concentrations with increase in aircraft noise
Morrell S, Taylor R, Carter N, Job S, Peploe P *(See also Morrell et al, 2000)*	Cross-sectional relationship between blood pressure of school children and aircraft noise	Carter N, Job RF, eds. Noise Effects '98. Proceedings of the 7th International Congress on Noise as a Public Health Problem: Sydney; 1998. Noise Effects Pvt. Ltd.: Sydney; 1998. p 275-9.	1998	Aircraft noise and blood pressure	1,230 primary school children (males & females, aged ≥ 8 years)	Australian Noise Energy Index (ANEI): 15 to 45	Difference in mean systolic BP = -1 mmHg (not significant) Difference in mean diastolic BP = -1 mmHg (not significant)	Sydney, Australia Cross-sectional study Mean blood pressure difference of 1 mmHg across noise range; not significant Variations in BP levels not associated with changes in noise

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
								levels
Morrell S, Taylor R, Carter N, Peploe P, Job S *(See also Morrell et al, 1998)*	Cross-sectional and longitudinal results of a follow-up examination of child blood pressure and aircraft noise – The inner Sydney child blood pressure study	Inter Noise 2000. The 29th International Congress and Exhibition on Noise Control Engineering: Nice; 2000	2000	Aircraft noise and blood pressure	628 primary school children (males & females, aged ≥ 8 years)	Change in ANEI: -5 to +5	Difference in mean systolic BP = 0 mmHg (not significant) Difference in mean diastolic BP = 0 mmHg (not significant)	Sydney, Australia Prospective cohort study Changes in BP levels over time were not associated with noise levels
Müller D, Kahl H, Dortschy R, Bellach B *(See also Bellach et al, 1995)*	Umwelteinwirkungen und Beschwerdenhäufigkeit, Ergebnisse einer Kohortenstudie	SozEp-Hefte 2/1994, Berlin, Institut fur Sozialmedizin und Epidemiologie, Bundesgesundeitsamt, 1994.	1994	Traffic noise heard at home & noise annoyance and hypertension, angina pectoris & myocardial infarction	1,002 adults (males & females, aged 40–65 years)	Annoyance at traffic noise	RR = 0.92 with ‘global’ disturbance RR = 2.32 with reported sleep disturbance (significant)	Germany General population follow-up study / Cross-sectional study
Neus H, Eiff AW, Rüddel H, Schulte W *(See also Eiff and*	Traffic noise and hypertension. The Bonn traffic noise study	Rossi G, ed. Proceedings of the 4th International Congress on Noise as a	1983	Traffic noise and hypertension, blood pressure & myocardial	165 adults (males & females, aged 20–49 years)	L_{DAY}: <60 dBA vs. >65 dBA	Difference in mean systolic BP = 1 mmHg (not significant) Difference in	Bonn, Germany Cross-sectional study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
Neus, 1980; Eiff et al, 1981)		Public Health Problem: Turin; 1983. Edizioni Tecniche a cura del Centro Ricerche e Studi Amplifon: Milano, 1983. p 693-8.		infarction			mean diastolic BP = 1 mmHg (not significant) For hypertension: RR = 1.52 (significant; 95% CI: 1.02–1.15) For myocardial infarction: RR = 1.30 (not significant; 95% CI: 0.44–3.56)	
Niemann H, Maschke C	WHO Large analysis and review of European housing and health status (LARES) final report: Noise effects and morbidity	Interdisciplinary Research Network 'Noise and Health': Berlin	2004	Traffic / neighbourhood noise, noise annoyance & sleep disturbance and hypertension & myocardial infarction	5,442 subjects, including children (aged 1-17 years), adults (aged 18-59 years), and the elderly (aged 60 years and older)	Strong annoyance from general traffic noise Strong annoyance from general neighbourhood noise	For hypertension: OR = 1.588 For cardiovascular symptoms: OR = 1.545 For hypertension: OR = 1.706 For cardiovascular symptoms:	Part of the WHO LARES study, which collected data on over 3,000 dwellings & 8,500 inhabitants in 8 cities in Europe: Angers (France), Bonn (Germany), Bratislava (Slovakia), Budapest

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
						Sleep disturbance from noise	OR = 1.601 For hypertension: OR = 1.485 For cardiovascular symptoms: OR = 1.449	(Hungary), Ferreira do Alentejo (Portugal), Forlì (Italy), Geneva (Switzerland), and Vilnius (Lithuania)
Pulles MP, Biesiot W, Stewart R *(See also Altena et al, 1988)*	Adverse effects of environmental noise on health: An interdisciplinary approach	Environ Int; 16:437-45	1990	Traffic & military aircraft noise and ischaemic heart disease & blood pressure	829 adults (males & females, aged 22–55 years)	Aircraft noise >~55 dBA Traffic noise from ~51–75 dBA L_{DEN} ≤60 vs. >56 dBA	For IHD: Prevalence ratio mainly > 1.0; range = 0.77–1.48 (but none are significant) Prevalence ratio mainly < 1.0; range = 0.52–1.03 (but none are significant) For blood pressure: Difference in mean systolic BP = -1 to +5 mmHg (significant; $p<0.05$)	Four cities in the Netherlands: Groningen, Twenthe, Leeuwarden, Amsterdam Cross-sectional study No dose-response relationship found for IHD and aircraft or traffic noise No clear pattern observed for noise and blood pressure

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
							Difference in mean diastolic BP = -1 to +2 mmHg (not significant)	
Regecová V, Kellerová E	Effects of urban noise pollution on blood pressure and heart rate in preschool children	J Hypertension; 13:405-412	1995	Traffic noise and blood pressure & heart rate	1,542 children (aged 3-7 years)	Long-term exposure to high-level urban traffic noise ($L_{eq,\ 24h}$) 61–69 dBA (noisy) > 70 dBA (very noisy)	Both systolic and diastolic BP significantly elevated in noisy or very noisy environments. Significant heart rate decrease with higher traffic noise levels. Greater effects observed in older children	Bratislava, Slovakia Cross-sectional study Results quoted as mean values of BP and heart rate rather than as OR / RR. Noise at the kindergartens had greater impact than noise at home
Rohrmann B *(See also Eiff et al, 1974)*	Das Fluglärmprojekt der Deutschen Forschungsgemeinschaft,	Harald Boldt Verlag KG	1974	Aircraft noise and blood pressure	392 adults (males & females, aged 21–60 years)	$L_{max,mean}$: <87 dBA vs. >95 dBA	Difference in mean systolic BP = 2 mmHg Difference in	Munich, Germany Cross-sectional study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
	Kurzbericht, Boppard						mean diastolic BP = 3 mmHg	BP differences not significant
Rosenlund M, Berglind N, Pershagen G, Jarup L, Bluhm G	Increased prevalence of hypertension in a population exposed to aircraft noise	Occup Environ Med; 58:769-773	2001	Aircraft noise and hypertension	2,959 adults aged 19-80 years (266 living near the airport; 2,693 living elsewhere in the county)	Energy-averaged aircraft noise > 55 dBA Maximum aircraft noise > 72 dBA	OR = 1.6 (adjusted) OR = 1.8 (adjusted)	Stockholm, Sweden Cross-sectional study Prevalence OR adjusted for age, sex, smoking and education Other confounders (e.g. diet, exercise, residential type) not significant Weakness: Self-reported health indicators
Schulte W, Otten H	Results of a low-altitude flight noise study in Germany: Long-term extra-aural effects	In: Ising H, Kruppa B, eds. Lärm und Krankheit – Noise and Disease. Proceedings of	1993	Military aircraft noise & low-altitude flight zones and blood pressure &	7,189 adults (males & females, aged 20–60 years) in phone	Telephone survey Clinical examinations (Münsterland)	Response rate = 56% Response rate = 6% (very low)	Münsterland, Franken, and military low-altitude flight zones in Germany

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
		the International Symposium: Berlin, 1991. Gustav Fischer Verlag: Stuttgart; 1993, p328-38		hypertension	survey; 413 adults (males & females, aged 20–60 years) in Münsterland study; 424 adults (males & females, aged 40–60 years) in Franken	Clinical examinations (Franken) More vs. less sound-exposed areas in Münsterland More vs. less sound-exposed areas in Franken	Response rate = 49% For clinically examined hypertension cases: Prevalence ratios = 1.0 (males); 0.9 (females) (not significant) Prevalence ratios < 1.0 in exposed subjects (not significant)	Telephone survey followed by cross-sectional study No difference in prevalence of high BP Weaknesses: Low response rate; single event noise levels were used rather than average sound levels
Schulze B, Ullmann R, Mörstedt R, Baumbach W, Halle S, Liebmann G, et al	Verkehrslärm und kardiovaskuläres Risiko– Eine epidemiologische Studie	Dt Gesundh Wesen; 38:596-600	1983	Traffic noise and hypertension & cardiovascular problems	700 adults (males & females, aged 20–75 years)	Noise levels >70 dBA	RR for requiring antihypertensive drugs = 5.0 (significant; $p<0.05$) RR for requiring cardiovascular drugs = 5.0	Erfurt, Germany Survey Hypertension inferred from purchase of antihypertensive & cardiovascular medication from pharmacies

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
							(significant; p<0.05)	Weakness: Risk estimates given as proportional morbidity ratios (PMRs)
Tobias A, Diaz J, Saez M, Alberdi JC	Use of Poisson regression and Box-Jenkins models to evaluate the short-term effects of environmental noise levels on daily emergency admissions in Madrid, Spain	Eur J Epidemiol; 17:765-71	2001	Traffic noise & air pollution and emergency hospital admissions (including for circulatory and respiratory causes)	1,096 emergency hospital admissions	Emergency admissions for: All causes Circulatory Respiratory	Per increase in 1 dB noise: RR = 1.054 (95% CI: 1.041–1.067) RR = 1.044 (95% CI: 1.018–1.071) RR = 1.038 (95% CI: 1.011–1.067)	Madrid, Spain Time series study Madrid has high background noise level: > 65 dB for more than 90% of days during study period (1995–1997)
Van Kempen E, van Kamp I, Fischer P, et al	Noise exposure and children's blood pressure and heart rate: the RANCH project	Occup Environ Med; 63:632-39	2006	Aircraft & traffic noise and blood pressure & heart rate	1,283 children (aged 9–11 years) attending primary schools near two European airports	$L_{Aeq,\ 7–23hr}$ (day)	Chronic aircraft noise at home (day): Systolic BP: + 0.10 mmHg/dBA (significant; 95%CI: 0.00 – 0.20)	Heathrow Airport (London, UK) and Schiphol Airport (Amsterdam, Netherlands) Road traffic noise related to decrease in blood

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
						$L_{Aeq, 23–7hr}$ (night)	Diastolic BP: + 0.19 mmHg/dBA (significant; 95%CI: 0.05 – 0.32) Chronic aircraft noise at home (night): Systolic BP: + 0.09 mmHg/dBA (significant; 95%CI: 0.00 – 0.18) Diastolic BP: + 0.07 mmHg/dBA (not significant; 95%CI: -0.01 – 0.14)	pressure
Willich SN, Wegscheider K, Stallmann M, Keil T	Noise burden and the risk of myocardial infarction	Eur Heart J; 27:276-82	2006	Environmental noise and myocardial infarction	4,115 patients confirmed with acute MI (3,054	Environmental noise	For women: Adjusted OR = 3.36 (significant; 95% CI: 1.40–	Berlin, Germany Case-control study

Author(s)	Title	Publication / Publisher	Year	Area of Study	Subjects	Noise Levels / Classifications	Results	Remarks
					men aged 56 ± 9 years & 1,061 women, aged 58 ± 9 years), from 32 hospitals		8.06) For men: Adjusted OR = 1.46 (significant; 95% CI: 1.02–2.09)	Part of the 'Noise and Risk of Myocardial Infarction' (NaRoMI) study Risk of MI associated more with chronic noise exposure than with annoyance at the noise
						Annoyance by environmental noise (day)	For women: Adjusted OR = 1.25 (not significant; 95%CI: 0.93–1.67) For men: Adjusted OR = 1.04 (not significant; 95%CI: 0.87–1.23)	
						Annoyance by environmental noise (night)	For women: Adjusted OR = 1.28 (not significant; 95%CI: 0.82–2.00)	

Author(s)	**Title**	**Publication / Publisher**	**Year**	**Area of Study**	**Subjects**	**Noise Levels / Classifications**	**Results**	**Remarks**
							For men: Adjusted OR = 1.12 (not significant; 95%CI: 0.88–1.44)	
Yoshida T, Osada Y, Kawaguchi T, Hoshiyama Y, Yoshida K, Yamamoto K	Effects of road traffic noise on inhabitants of Tokyo	J Sound Vibration; 205(4):517-522	1997	Traffic noise and ischaemic heart disease	366 adult females (aged 20–60 years)	$L_{eq(24h)}$ > 65dBA	For history of heart disease: OR of relative risk = 3.1 (significant; $p<0.05$)	Tokyo, Japan Questionnaire-based study, in which all participants lived on either side of a main road (covering an area of about 16 ha)

WORKING PAPER

ON

A REVIEW OF SLEEP DISTURBANCE EFFECTS WITH TRANSPORTATION NOISE

FOR

THE PROVISION OF SERVICE FOR THE STUDY OF HEALTH EFFECTS OF TRANSPORTATION NOISE IN HONG KONG

ENVIRONMENTAL PROTECTION DEPARTMENT, HKSAR GOVERNMENT

TENDER REF. AN 08-047

Prepared by Dr. Irene van Kamp, Netherlands

April 2011

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1. Introduction

1.1 Aim and background

The Environmental Protection Department (EPD) of the Hong Kong SAR Government is planning a field survey in 2009 into the relationship between transport related noise and health in Hong Kong. This study aims to ascertain the health effects of transportation noise in Hong Kong by undertaking literature reviews of three health effects (annoyance, sleep disturbance and cardiovascular effects), a review on the noise criteria and metrics needed to maintain a good acoustical environment in Hong Kong and a questionnaire study of noise health effects, particularly annoyance, due to transportation noise in Hong Kong.

This working paper provides an updated review on sleep disturbance, which was identified as one of three non auditory health effects of transportation noise in a pilot study by CUHK in 2002 (Wong, 2002). This review has been based on the literature available from the WHO, the EU and the US, and also makes use of some unpublished work and papers and relevant research findings. Based on his extensive literature review Wong concluded that in population-based studies, complaints of symptoms or increased reports of disorders are found among those exposed to noise levels of 65 dB(A) or above. However, disturbance of sleep quality and physiological (as shown by electroencephalography or electromyography) changes in sleep pattern have been shown to occur at a noise level as low as 45 dB(A). In general sleep disturbance is a major outcome of environmental noise. Poor sleep quality not only results in mental and psychosocial symptoms such as fatigue, sleepiness, headache, depression and irritability, but also influences daily cognitive performance and health in the long term.

Against this background the available literature for the period 2002-2009 was systematically collected, evaluated and summarized. The review includes discussion, as far as possible, of the applicability of overseas findings with respect to noise and sleep in the Hong Kong situation.

1.2 Understanding sleep disturbance

Definition

Sleep is an active physiological process and defined ‘as a state of the brain and body governed neural systems and characterized by periodic, reversible loss of consciousness; reduced sensory and motor functions linking the brain with the environment; internally generated rhythmicity, homeostatic regulation, and a restorative quality that cannot be duplicated by food, drink or drug’(Aldrich, 1999).

Sleep disturbance or sleep disorder (somnipathy) is defined as a medical disorder of the sleep patterns of a person. Some sleep disorders are serious enough to interfere with normal physical, mental and emotional functioning. Common causes of sleep disorders are changes in life style, e.g. a change in shift work, anxiety, chronic pain (back, neck etc), low back pain (sciatica), incontinence, various drugs, endocrine imbalances, disorders of the circadian rhythm and environmental noise (source: http://en.wikipedia.org/wiki/Sleep_disorder).

Mechanisms

Sleep has been shown to be sensitive to environmental factors, and specifically, to ambient noise, as external stimuli are still processed by the sleeper’s sensory functions, despite a non-conscious perception of their presence. Unlike other physical ambient factors (i.e. electromagnetic fields or air pollutants), noise is perceived by the central nervous system by special sense organs, the ears. In urban areas, road and rail traffic noise are the most frequently reported noise source in relation to sleep disturbance, followed by noises from neighbours and aircraft noises. Sleep is a physiological state that needs its integrity to allow for normal restoration of the living organism. Reduction or disruption of sleep can, in the long term, be detrimental as chronic partial sleep deprivation induces tiredness, increases low vigilance state and reduces daytime performance and quality of life (Muzet, 2007).

The sleep cycle contains two main states: **rapid eye movement** (REM) and **non-rapid-eye movement** (NREM), while NREM is subsequently separated into 4 sleep stages. REM sleep features a low-amplitude, mixed frequency electroencephalogram EEG, with eye movements (EOG) showing bursts of REM activity similar to that seen during eyes-open wakefulness, and absent EMG activity due to brainstem-mediated muscle atonia that is characteristic of REM sleep. NREM (including slow wave) sleep is required for the brain to recover from fatigue, and REM sleep is necessary for physical recovery and essential for the maintenance of quality sleep (Kawada & Suzuki 1999). The sleep cycle begins with the shallow stage 1 of NREM sleep, progressing through to NREM stage 4 within 45-60 minutes, followed by 15 minutes of deeper REM sleep, then the cycle re-commences as NREM sleep, and so on. Sleep deprivation is known to cause increased rapidity of sleep onset, and an increase in the intensity and amount of slow wave sleep, which normally predominates the first one third of the night's sleep in young adults (Wong 2002). Figure 1 compares an undisturbed sleep pattern (top) with a noise disturbed sleep pattern (bottom). Top: Sleep onset occurs within 10 min after light out time (0). Sleep begins by NREM sleep stages and the first REM episode occurs some 90 min after sleep onset. SWS (stages 3 and 4) occurs mainly during the first 3 h of the night. REM sleep episodes appear at very regular intervals. No awakening is seen during the entire night. Bottom: during a noise-disturbed night. Sleep onset is slightly delayed. The first episode of stage 4 is partly interrupted. A significant amount of SWS does occur during the fifth hour (possibly as a compensatory mechanism of the disturbed first episode). REM sleep still shows clear rhythmic occurrence but some of the episodes are fragmented. Significant awakenings occur throughout the sleep process. Sleep efficiency is reduced (Muzet, 2007).

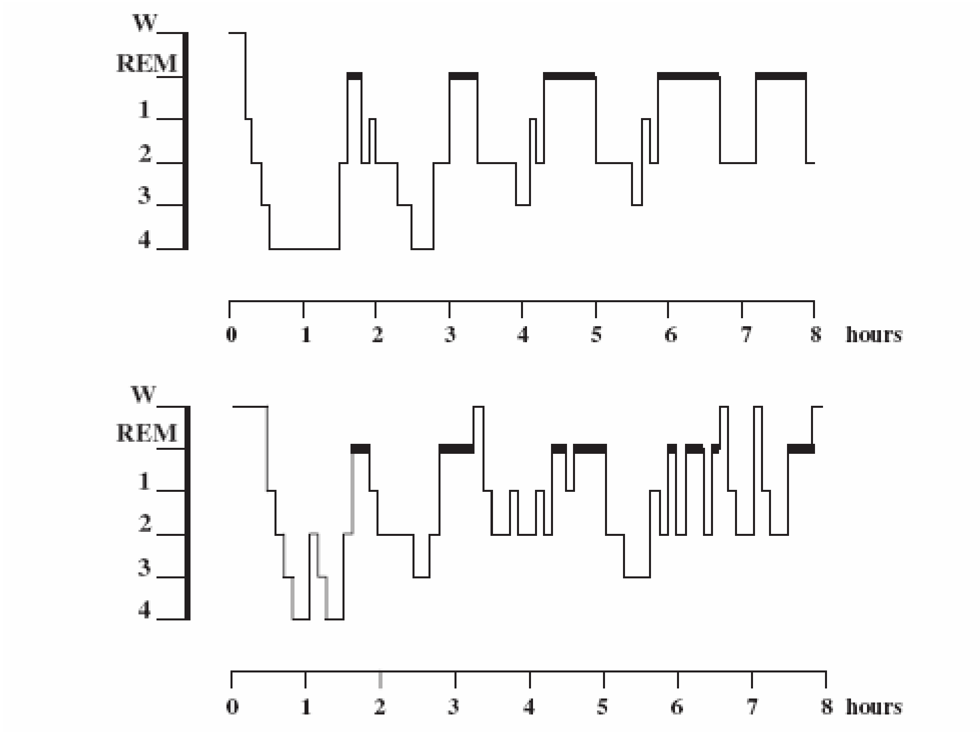

Figure 1: Hypnograms of a young adult (Source: Muzet, 2007)

Noise and health

It has been shown that nighttime noise can negatively affect people's sleep. The relationship between environmental noise and different aspects of sleep, and long term health effects, is a complex one. Several researchers have presented conceptual models to describe this complex interplay (see e.g. Porter et al, 2000; Ising and Babisch, 1999; Passchier, 2003). The model described by Porter et al (2000) is presented below as representative example of current thinking about the mechanism by which environmental noise can lead to sleep disturbance and health effects.

This model shows that noise can directly lead to acute effects and then through a chain to long term health consequences. Feedback mechanisms and modifying factors are assumed meaning that noise can lead to health consequences through indirect paths. This complex web of interactions makes it difficult to quantify any simple exposure-response relationship between noise exposure and health effects.

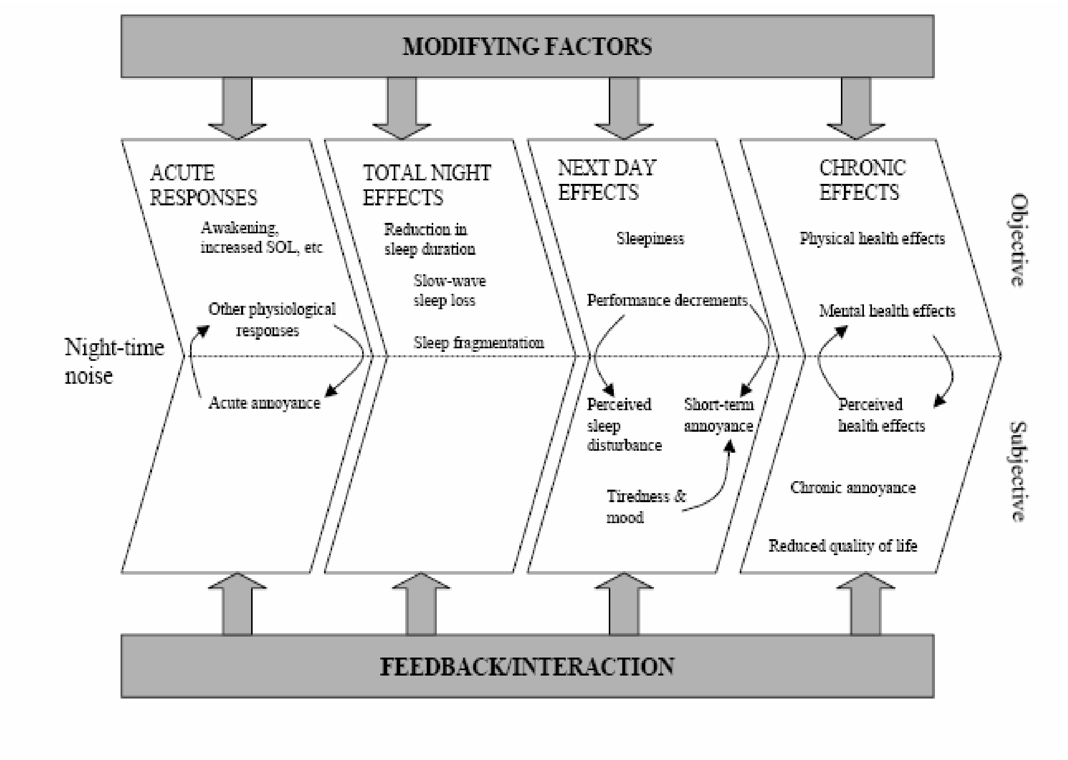

Figure 2: The conceptual model of noise and sleep (Source: Porter et al, 2000)
* SOL: Sleep Onset latency

In the model a distinction is made between:

1) acute responses that include immediate or direct disturbances caused by noise events,
2) total night effects that are aggregations of (1) over the whole night,
3) next day effects that are a result of (1) and (2), and
4) chronic effects that are pervasive long-term consequences of (1), (2) and (3).

Sleep disturbance is generally seen as an intermediate effect. It is assumed to be an initiator of diseases and/or it aggravates existing disease. Whether this will happen depends on the person's vulnerability and/or sensitivity (Cohen et al, 1986) (Berglund et al, 1999) (Van Kamp et al, 2004) (Staatsen et al, 2004). Potential vulnerable groups are people with a somatic or mental disorder, shiftworkers and the elderly. Evidence has shown (Eberhardt, 1990; Ohrstrom, 2006) that children are less sensitive for awakenings and sleep cycle shifts. but more sensitive for physiological effects such as blood pressure reactions (Muzet, 2007).

Measurement of sleep disturbance

Sleep disturbance is a multi-faceted concept, referring to a broad range of effects from awakening to subtle changes in autonomic physiology, and these changes are not necessarily consistent within an individual for a given level of noise stimulus as there are complex patterns of neurophysiology associated with the different EEG defined sleep stages and the time of night. Given this complex process it can be seen that there are various end-points that can be chosen to assess the degree of sleep disturbance These range from measures extracted from the EEG based polysomnography, which is considered the 'gold-standard' of sleep recording and provides a direct measure of cerebral activity from which a number of macro and microstructural features can be extracted (Basner et al, 2008 - in Hume, 2008). Sleep disturbance also refers to subjective effects such as perceived quality of sleep or nighttime annoyance.

As a consequence, different methods and techniques are used to investigate the possible effects of noise on sleep disturbance and widely vary depending on the responses/effects being studied (see the model of Porter in the figure above). These methods can roughly be divided into two categories: physiological measures and self reported measures such as diaries and questionnaires. Table 1 gives an overview of physiological parameters, the underlying concept and their operationalisation.

Table 1: Overview of physiologic examinations used in studies investigating the possible effects of noise on sleep. (Source: van Kempen, Staatsen, and van Kamp, 2005

Type of examination	**Indicator for**	**What is examined ?**
Electroencephalograph (EEG)1)	The sleep stages	Total sleep time, total time spent overnight in Slow Wave Sleep(SWS; deeper sleep) and in the stage of Rapid Eye Movement (REM; dream sleep)
EMG[1] EOG[1] Electrocardiography (ECG) Plethysmography Actimetry	Muscle tone Eye-movements Cardiac function Heart rate and blood pressure Motility	Heart rate Total sleep time, time of falling asleep, wake-up time, Number of awakenings
Overnight cortisol in blood or fluvia Overnight urinary catecholamine	Level of circulating catecholamines Level of total catecholamines released during sleep, not taken up by sympathic nerve endings	Sympathetic nervous activity

[1]The measurement of brain activity by means of EEG, EMG and EOG is also called polysomnography (van Kempen et al, 2005)

Table 1 shows that awakenings can be measured and defined in several ways. A distinction is made between arousals (or EEG awakenings) and behavioural awakenings. An arousal is defined as an EEG response that has all the characteristics of an individual awake; behavioural awakening is confined to a verbal or motor response, indicating the subject is awake. Behavioural awakenings are often measured by use of a switch mounted on the headboard of the bed or by a micro-switch taped on the hand (Lukas, 1975). It has to be kept in mind that behavioural awakenings are only a rough evaluation of sleep disturbance, because changes in sleep architecture (such as sleep stage changes and short lasting EEG awakenings) can be totally missed if only behavioural awakenings are assessed. Awakenings can be related to both noise events and noise levels during a whole night (Pearsons, 1998).

The quality of the sleep can also be measured in a subjective way. After effects (non-acute) are usually measured subjectively using questionnaires on sleep quality, tiredness, and annoyance. More objective measures of after effects include excretion of hormones, sleepiness, task performance tests, and cognitive functioning tests.

The measurement of nighttime disturbance is often done by means of an interview or questionnaire in which standardized questions are included. Like annoyance, sleep disturbance questions vary between surveys, in wording and in the number or response categories. In order to obtain comparable disturbance measures the scales are often translated into a scale from 0 to 100. Cut-off points to assess the percentage of highly sleep disturbed persons are often used, analogue to the definitions of percentage (highly) annoyed persons (Miedema, 2003; 2007). Box 1 gives some examples.

- If aircraft noise wakes you up at night during weekday/weekend, how much does this annoy you? *(not at all, a little, quite, very much)*

- Does noise from <source> interrupt sleeping *(no, yes)*

- In the past 12 months when you were at home how much was your SLEEP disturbed by noise from each of the following sources. If your sleep was not disturbed at all tick 0. And if your sleep was disturbed extremely tick 10. Otherwise choose one of the numbers between 0-10. NOTE if you do not hear noise form this source, please tick: NOT APPLICABLE. (*11 point Likert scale ranging from not at all to extremely, or a 5 point scale with verbal labels (not at all, slightly annoyed, somewhat, moderately, very annoyed*) (based on the ISO standard, 2003: Fields *et al*, 1997; 2001).

- In the past **2 years** has a doctor diagnosed you with insomnia *(no, yes)*
- In the past **12 months** were you under treatment or control by GP or specialist for this disease you treated for insomnia *(no, yes)*
- In the past **2 weeks** were you taking medication for insomnia, <nervousness, anxiety> or were you taking sedatives or tranquilizers *(no, yes)*

- Which of the following statements are applicable to the quality of your sleep in the past one month?

At night I often do not sleep at all
I often get up at night
I usually toss and turn a lot during the night
I wake up more than once per night
I consider that I generally sleep very badly
Often it feels as if I only slept a few hours
I sleep often not longer than five hour
I think I usually sleep well at night
I generally go to sleep easily
I often lie awake in bed for more than half an hour before falling asleep
If I wake up at night I find it hard to get back to sleep
After getting up in the morning, I usually feel well rested

- (Source: Mulder-Hajonides van der Meulen)

1.3 Nighttime noise and sleep

Effects

In the period to 2002, several reviews and meta-analyses (HCN, 1994; WHO, 2000; Franssen and Kwekkeboom, 2003; Porter et al, 2000; Wong, 2002; Pearsons, 1989) have been published in the field of noise and sleep disturbance. Most studies in this area had an experimental design and field studies were scarce or restricted to a single noise source, in particular aircraft noise. In general, results convey that nighttime noise can adversely affect the sleep quality, daily functioning and mood of the people exposed, although results are highly variable and sometimes contradictory due to differences in design, outcomes, and a focus on different situations and environments. Results of laboratory studies and field studies are often hard to compare, and there is ongoing debate especially about the long-term health effects. In order to understand the detrimental effects on health and quality of life of nighttime-noise-exposed populations in the long term, some fundamental questions still need to be answered according to Muzet (2007).

Sleep disturbance occurs in different sleep domains: sleeping behaviour, sleep structure, physiological aspects of sleep, and after effects. These effects manifest themselves at different stages of the sleep process. A general distinction is made between:

- **Primary effects** such as difficulties falling asleep, awakening, and sleep cycle changes as well as physiological effects during the sleep such as a rise in blood pressure and heart rate, vasoconstriction, breathing and motility.
- **Secondary effects** or after effects such as perceived reduction of sleep quality, fatigue, deteriorated mood, reduced wellbeing and task performance.
- **Long term effects** on wellbeing such as increased medication use and chronic annoyance, reduced social functioning and other health indicators (e.g. hypertension).

Brief overview of findings until 2002

Wong (2002) reviewed 24 studies over the period of 1989 – 2001 pertaining to seven cross-sectional studies, eight observational studies and nine laboratory studies. He concluded that, in population-based studies, sleep disturbance as measured by self reported symptoms or by objective sleep parameters, are found among people who are exposed to noise levels of 65 dB(A) or above. However, disturbance of sleep quality and physiological changes (as shown by electroencephalography or electromyography) in sleep patterns have been shown to occur at a noise level as low as 45 dB(A). Based on an extensive review of the sleep literature, the WHO (Berglund *et al*, 1999) advised that, for a good sleep, indoor sound pressure levels should not exceed approximately 45 dB(A). Equivalent sound pressure levels and the number and level of sound events should be taken into account, and acoustical context also considered, when defining threshold levels (e.g. situations with low background noise levels, combined noise and vibration from, for example, heavy trucks or trains) and combined exposure to transport noise and low frequency noise.

Based on these previous reviews and meta-analyses the findings are summarized briefly (original references not shown—see the original reviews for specific sources).

Primary sleep disturbance effects and physiological effects of noise have been found in several experimental studies. These include increased sleep latency time; awakenings; and alterations of sleep stages or depth, especially a reduction in the proportion of REM-sleep (REM = rapid eye movement). The REM sleep is considered as particularly sensitive to noise exposure. Physiological effects i.e. increased blood pressure; increased heart rate; increased finger pulse amplitude; vasoconstriction; changes in respiration; cardiac arrhythmia; and an increase in body movements during sleep, have been identified as acute effects of noise exposure—each with their own thresholds and dose response relationship. Meta-analyses of field and laboratory studies regarding these effects have suggested that there is a relationship between the sound exposure level (SEL) for a single night-time noise event and the percentage of people awakened, and sleep stage changes. The most important result of the meta-analyses is, according to Berglund (1999), that there is a clear difference in the dose-response curves derived from laboratory and field studies, and that noise has a lower effect under real-life conditions.

Secondary effects refer to effects measured the day following the night-time exposure; also referred to as after effects. The secondary effects found in relation to environmental noise include reduced perceived sleep quality, increased fatigue, depressed mood or well-being, and decreased performance.

Long-term effects on psychosocial well-being (annoyance, medication use, perceived quality) have also been related to noise exposure during the night. Other frequently reported behavioural effects of night-time noise include closing bedroom windows and the use of personal hearing protection. Questionnaire data indicates the importance of night-time noise on the perception of sleep quality. Measures of perceived sleep quality (difficulty in falling asleep; waking up during sleep; waking up too early; feelings of sleeplessness one or more days a week) have been found to correlate significantly with the average traffic volumes during night-time. Measured disruption of the sleep cycle has been shown to be significantly associated with personal evaluation of poorer sleep quality. Sensitive groups include the elderly, shift workers, persons especially vulnerable to physical or mental disorders and other individuals with sleeping difficulties.

Long-term health effects

Only a few studies have been performed on the long term health effects of noise. Wong reports on one study where an increased reporting of cardiovascular disease histories was associated with noise exposure levels above 65 dB(A), Leq. The crucial question concerning the causal linkage between environmental noise, primary and secondary effects on the one hand and the hypothesized contribution to multi-factorial chronic diseases, to chronic annoyance, and to permanent behavioral alterations, on the other hand, remains to be answered (Griefahn, 2002). Only insight in this causal network could clarify the significance of the various primary and secondary effects which are as yet insufficiently studied, e.g. the time for falling asleep, premature awakenings, performance the next day (i.e. productivity), accident risk, and social life (Porter et al, 2000; Berry and Jiggins, 1999; HCN - Health Council of the Netherlands, 1994).

Exposure-response relations from previous studies

Wong identified two publications reporting a dose-response relationship. Dose response relationships have been derived for a limited number of sleep indicators: awakenings and shifts in sleep stages while sleep quality, mood, task performance, and medication use were not included (for an overview see van Kempen et al (2005) and Table 2). The critique on these relationships (see e.g. Berglund, 1999) are directed at the fact that the noise exposure characterization was inadequate, and important modifiers such as ventilation in the bedroom, and insulation measures in the home have been neglected (Berglund, 1999). Moreover these dose response relations were derived from laboratory studies and the relationships were often not source specific (Muzet, 2002). Also, results from laboratory results systematically deviate from those measured in the field. Pearson (1989) concluded that the slope of the relationships derived from laboratory studies was much steeper than those from field studies, which is possibly a result of precision in exposure estimates/measurements. Muzet (2002) gave an overview of the papers reviewing dose response relations (see Table 2).

Table 2: Overview of dose response relationships in the early literature to 2001 (Source: Muzet, 2002)

Authors	Year	Number of studies	Site	Type of noise	Noise exposure measures *	Effects considered (curves)
Lukas	1975	13	Lab.	Aircraft, sonic boom & road traffic	L_{Amax}, EPNL & SENEL	Awakening, arousal & no sleep disruption
Griefahn	1980	10	Lab.	Aircraft, train, white noise, tones & road traffic	L_{Amax}	Awakening & 0-reaction
Pearsons	1989	21	Lab. & field	Aircraft, train, white noise, tones & road traffic	L_{Amax} & SEL	Awakening or aroused & sleep disruption
Hofman	1994	53	Lab & field	Aircraft, road traffic, train, industry, mixed	L_{Amax}	Awakenings & sleep stage changes

* L_{Amax}: maximum A-level; PNL: perceived noise level; EPNL: effective perceived noise level; SEL: sound exposure level; SENEL: single event noise exposure level.

Miedema (1998) published dose-response relationships based on analysis of a pooled data of 20 studies for sleep disturbance attributed to noise. Aircraft noise was shown to be more disturbing than road traffic and rail noise (see figure 3). These analyses have been updated in 2003 and 2007 adding four studies to the pooled analysis and will be discussed in more detail in paragraph 3.1.1.

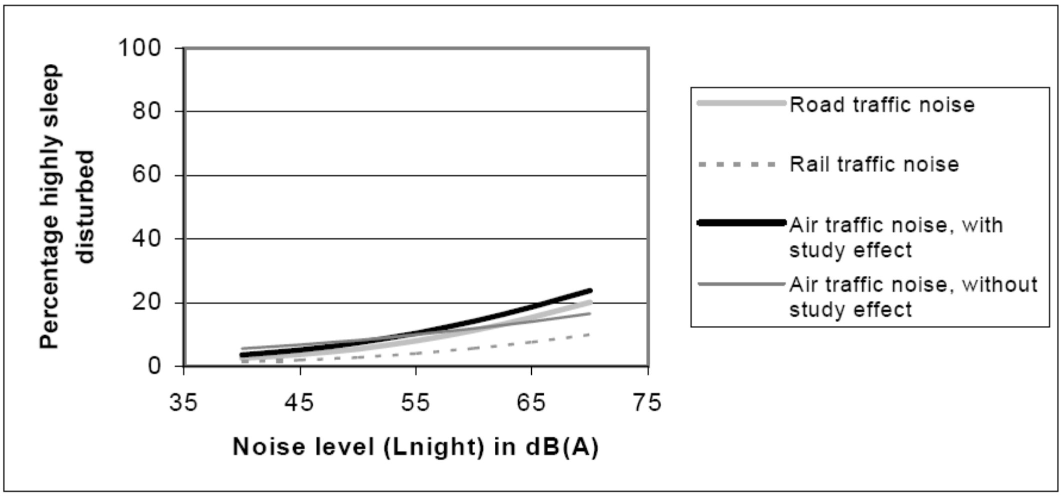

Figure 3: Exposure-effect-relationships between night-time noise exposure (L_{NIGHT}, outside) at most exposed façade) and self-reported sleep disturbance for exposure to road, rail, and air traffic noise (Source: Miedema et al,2003; Miedema and Oudshoorn, 2004)

1.4 Knowledge gaps and limitations

Several issues and limitation have emerged over recent years and can be taken as a point of departure for the update of the reviews:

- Outcomes are often based on small sample sizes.
- Restriction in age and gender groups.
- Outdoor exposure levels were often used as proxy for indoor.
- Only awakening and sleep stage changes were considered as effect outcomes.
- Contextual variables such as the sound insulation of the buildings, windows open or closed/ ventilation behaviour, combined noise sources etc. have often not been accounted for.
- At the personal level, aspects as age, sensitivity and sleeping behaviour have also not been systematically considered.
- Habituation issues: habituation was found in several laboratory studies but, due to unrealistic noise exposure characterization, these findings might not be applicable to real life situations. This might indicate that the time interval between two noise events also has an important influence on the probability of obtaining a response. Moreover, evidence on habituation is restricted to awakenings but not available for physiological, perceived quality and other after effects. The autonomic responses do not habituate.
- In surveys, sleep disturbance is often measured in terms of night time annoyance and less frequently by sleep quality. These two are not, per se, comparable.

2. Method

2.1 Literature search

Our literature search on the impact of environmental noise on sleep is partly based on a method as described by van Kempen (2002) and de Hollander (1996) and performed in a systematic manner. However, no endeavor was made to quantify the findings in a systematic way. An important problem with systematic reviews and meta-analysis is publication and presentation bias, referring to the phenomenon that positive outcomes are more easily published and presented than negative outcomes which could lead to an overestimation of effects. By using a broad search profile we have tried to avoid this type of distortion as much as possible. Biographical sources were searched for the period of 2002 to 2009. Important sources included MEDLINE, EMBASE, PSYCINFO and SCISEARCH and were matched for duplications Keywords included a combination of:

- **Noise –** noise; noise pollution; noise effects
- **Transport –** traffic ; road; road-traffic; road-transport; automobile; vehicle; vehicular movements; motorcycle; tram; train; trains; railway; railroad airplane; aeroplane; aircraft; airport; air-traffic; night flights; transportation; traffic; motor vehicles; motor vehicle; railroads; railroad; trains; railway; airport; aviation; aircraft; air)
- **Sleep –** insomnia; awakening; sleep disorders; sleep-deprivation; sleep onset; sleep pattern; wakefulness; disturbance

2.2 Selection

In view of the aim of this working paper the following *a priori* criteria have been formulated:

- The working paper takes the review of Wong (2002) as a starting point and updates this based primarily on reviews published in the period from 2002- to 2009, rather than on all separate publication since 2002;
- The review focuses on transportation noise and excludes other sources including low frequency noise;
- Studies into primary effects, secondary effects as well as chronic effects are included;
- The review is primarily aimed at population based studies (clinical and observational);
- Experimental studies are also included but only if directed at transportation noise;
- Specific attention is given to the relevance of the findings for the HK situation, and their applicability where appropriate;
- Specific attention is also given to exposure characterization;
- The review is systematic but descriptive and will not summarize the selected studies in a quantitative manner by means of meta- analysis;
- In addition policy documents, guidelines and position papers were included in the review as well as key reports (not published in peer reviewed journals) and papers from conference proceedings which were referred to in these documents (so called snow ball method);
- Available results on vulnerable groups such as different age groups and socioeconomic classes were also examined.

2.3 Data extraction

Bearing these criteria in mind, the descriptive review was based in the first place on existing reviews over the period 2002-2009 and subsequently on the selected peer review papers (full papers or abstracts). The relevant data were extracted in a table containing information on *author*, *source, title, study design, subjects, exposure assessment, non-auditory health outcomes, confounding factors, main results and conclusions, and limitations*. (Tables A1 and A2). Information of the reviews are presented in a separate table (Table A3).

This search yielded some 12 reviews and 102 peer reviewed journal articles. After dropping duplicates and papers which only marginally focused on sleep disturbance (including more general reviews on noise and health) 58 documents were maintained. Of the 58 peer reviewed papers 15 pertain to field studies and 43 to laboratory studies, 25 to road traffic noise, 28 aircraft and 12 to rail noise. Many investigations were reported in more than one paper; multiple studies were sometimes reported in a single paper; and several were re-analyzed and re-reported by several authors (see, for example Basner) but these have been included as separate publications in the tables - a set of some eighty in total (for an overview of the full search please see Appendix III).

3. Results

Since 2001 some twelve reviews have been published including five peer reviewed papers (Raschke, 2004; Spreng, 2004; Michaud, 2007; Miedema, 2007; Muzet, 2007), seven policy and position papers and preparatory papers for these (EC, 2004; TNO, 2004; HCN, 2004; Kempen et al, 2005; Muzet, 2002; Berry, 2009; WHO, 2009; Basner and Griefahn, 2008) and a conference paper. (Hume, 2008). In 2007 the WHO published a draft version of the updated nighttime noise guidelines (NNGL), including several non-edited reviews on nighttime noise related issues. In the same year Miedema (2007) published an update of dose response relations for subjective sleep disturbance based on a reanalysis of a pooled data set of 24 studies. Four new studies were added to previous analyses. Only the papers of Michaud (2007), Spreng (2004) and Raschke (2004) can be defined as reviews in the stricter sense of the word, all three pertaining to aircraft noise, but each addressing different endpoints: sleepdisturbance, cortisol secretion and medication use respectively.

Before discussing the 2002-2009 literature in more detail, these major reviews are summarized chronological and per type of review (policy papers and their scientific background materials (attached as appendix), specific topic and reflective review. Subsequently, recent findings are discussed in more detail based on the selected papers. In order to systemize the presentation of the findings, the results of the peer reviewed papers are discussed according to study design and noise source. Then a special paragraph will discuss exposure related aspects such as noise metrics and noise events, and the effect of changes of noise. An update of available dose response relations and WHO proposed threshold levels are then presented. The influence of other (non acoustical) factors such as vulnerability, cultural differences and habituation will be discussed under the headings of different types of studies where available. In order to evaluate the progress made in the field in the past eight years, this review then lists and updates the limitation based on previous reviews in the conclusions. Finally, some initial observations and evaluations are made about the relevance and potential applicability of the findings of this review of noise and sleep to the HK situation.

3.1 Previous reviews: a summary

Table 3 gives a chronological overview of the reviews published in the period between 2002-2009. Since the different reviews show quite some overlap and are strongly interdependent, in the text they have been grouped accordingly. A distinction was made between general and specific topic reviews. A distinction was further made between policy papers and scientific background papers and more reflective reviews, describing the main issues, developments and directions for future research. Specific information about noise metrics, dose response relations and threshold levels are discussed separately.

Table 3: Overview of review documents period 2002-2009

Year	Author/Source	Tiltle
2002	Muzet, A.	Noise exposure from various sources sleep disturbance, dose effect relationships on adults WHO background paper
2004	Raschke F.	Arousals and aircraft noise - environmental disorders of sleep and health in terms of sleep

		medicine.**[Review]** [28 refs] Noise & Health. 6(22):15-26, 2004 Jan-Mar.
2004	Spreng M.	Noise induced nocturnal cortisol secretion and tolerable overhead flights. [Review] [50 refs]Noise & Health. 6(22):35-47, 2004 Jan-Mar.
2004/revised 2005	Health Council Netherlands	The influence of nighttime noise on Sleep and Health, The Hague, 2004/14E
2004	Miedema HME, Passchier-Vermeer W, Vos H.	Elements for a position paper on night-time transportation noise and sleep disturbance. Delft: TNO INRO 2002-59, 2003.
2004	EC working group on health and socio-economic aspects	Position paper on dose effect relationships for night time noise; nr:
2005	RIVM/Van Kempen, E. Staatsen BAM, van Kamp, I.	Selection and evaluation of exposure response relationships for HIA in the field of noise and health. Rep nr 63040000/2005
2008	Basner, M. Griefahn, B.	Environmental noise and sleep disturbance, Background paper for WHO, working group on risk assessment of environmental
2007	Finegold L., Muzet, A., Berry, B.	Sleep disturbance due to transportation noise exposure
2007	Michaud, D.	Review of field studies of aircraft noise induced sleep disturbance JASA 2007
2007	Miedema H.et al	Association between Self reported sleep disturbance and environmental noise based on reanalysis of pooled data from 24 studies Behav Sleep Med.
2007/ 2009	WHO	Night noise guidelines for Europe
2008	Hume K.	Sleep disturbance due to noise Research over the past 5 years ICBEN 2008
2007	Muzet, A	Environmental Noise, sleep and health. Sleep Medicine Review, 11, 2, 135-142
2009	Berry, B., Flindell, I.	Berry Bernard F, Ian H Flindell (2009) Estimating Dose-Response

	Defra	Relationships between Noise Exposure and Human Health Impacts in the UK TECHNICAL REPORT Bel Environmental Ltd, , Ian Flindell Associates

3.1.1 General reviews

Policy papers
The WHO published the night time noise guidelines (NNG) in 2009, based on several background papers. The NNG is presented as an extension of the Guidelines for Community Noise (2000). The need for such guidelines originated in the European Union Directive 2002/49/EC relating to the assessment and management of environmental noise (commonly known as the Environmental Noise Directive and abbreviated as END) which compelled European Union Member States to produce noise maps and data about night exposure from mid-2007. The information in the WHO guidelines also builds on the EC Position paper (2004) regarding night time noise exposure which was primarily focused on deriving dose effect relationships. This issue will be further described in paragraph 3.4.

The WHO Guidelines for Community Noise, published in 2000, also addressed night noise—based on studies carried out up to 1998. Since then new studies have become available, together with new insights into normal and disturbed sleep. The currently recommended guideline values of L_{NIGHT}, outside = 30 dB, 40dB, 55 dB are not directly comparable with the 2000 guideline value of L_{MAX}, inside = 45 dB(A) because the sound level units are different.

Regarding noise indices it was decided that long-term health effects such as cardiovascular disorders are more correlated with indicators summarizing the acoustic situation over a long time period, such as yearly average of night noise level outside at the façade (L_{NIGHT}, outside), while instantaneous effects such as sleep disturbance are more applicable to the maximum level per event (LA_{MAX}), (e.g. passage of a truck, airplane or train). Especially important in the framework of this working paper is the WHO approach to sleeping time, taking 7.5 hours as average sleeping time. Since sleep patterns and duration vary strongly due to personal factors like age and genetic make-up, (but possibly also cultural factors) there is considerable variation in sleeping time and in beginning and end times. For these reasons, a fixed interval of 8 hours is considered as a minimal choice for night protection.

Evidence on main issues was summarised as follows:

- Sufficient evidence for biological effects of noise during sleep: increase in heart rate, arousals, sleep stage changes, hormone level changes and awakening.
- Sufficient evidence that night noise exposure causes self-reported sleep disturbance, increase in medicine use, increase in body movements and (environmental) insomnia.
- While noise-induced sleep disturbance is viewed as a health problem in itself (environmental insomnia) it also leads to further consequences for health and well-being.
- Limited evidence that disturbed sleep causes fatigue, accidents and reduced performance.
- Limited evidence that noise at night causes clinical conditions such as cardiovascular illness, depression and other mental illness. It should be stressed that a plausible biological model is available with sufficient evidence for the elements of the causal chain.

- Children, elderly, pregnant women, shiftworkers and (chronically) ill people have been identified as vulnerable groups

Specific topics reviews
The literature review of Michaud et al (2007) discussed recent field studies of aircraft noise-induced (subjective) sleep disturbance. They conclude that from the literature it is apparent that aircraft noise-induced sleep disturbance occurs more often during later than earlier parts of the night; that indoor sound levels are more closely associated with sleep disturbance than outdoor measures; and that spontaneous awakenings, or awakenings attributable to non-aircraft indoor noises, occur more often than awakenings attributed to aircraft noise. The authors warn against an over-simplification of the findings as a basis for population level predictions of sleep disturbance due to aircraft noise, and that these reports should be treated with caution in developing regulatory policy for aircraft noise.

Spreng's paper (2004) reviews 50 studies on cortisol secretion in relation to the number of aircraft flights, and includes only a few new studies after 2001. It is concluded that noise induced cortisol increases due to noise levels below the level of awakenings might have effects which are relevant for health. Chronic elevations at lower levels are related to a broad range of diseases such as diabetes, CVD, osteoporosis and immune-related illnesses as well as gastric ulcers. The maximum levels for these effects is lower than that of awakening reactions and estimated to be 53 L_{MAX} on the ear. These levels match with the maximum levels for awakenings as reported by Basner et al (2001). He calculated an allowable number of 13 events with L_{MAX} indoor levels of 53, which is somewhat higher compared to Griefahn 10 events of L_{MAX} 53dBA. The 53 dBA threshold does not seem to be extreme in comparison to what has been suggested by others. However it should be kept in mind that it concerns hormonal responses. The long-term health effects of these changes are still under debate.

Raschke (2004) gives an overview of the current insights in sleep disturbance, EEG and vegetative arousals in relation to health, wellbeing and performance capacity. The review is again primarily on based literature to 2001. It is concluded that the long-term health effect of noise induced sleep disturbance (measured at different levels) cannot be estimated yet based on existing evidence. It is suggested that more attention should be given to increased metabolism. Sleep fragmentation also needs further study. Epidemiological research over long episodes and over many years are seen as the best way to gain insight in the effect of noise induced sleep disturbance on short (day after) and long term health (chronic and persistent) effects.

Reflective papers
In his five year review presented at ICBEN in 2008 Hume addresses several topics that are relevant for noise and sleep related issues. He indicates that the field could profit from new developments in the general sleep field, especially regarding cognitive effects (memory) and descriptions of normal sleep in terms of arousals etc. Most recent work is related to transport noise, as it was in the past. There are many indications that the number of people exposed to transportation noise and particularly to aircraft noise will increase over the next 20-30 years worldwide. There is ongoing discussion about the appropriate noise metrics to be used, and despite the fact that the EU has adopted sound pressure levels as standard (L_{DEN}, L_{NIGHT}), there is a clear need for additional descriptors. Major development since 2003 has been the publication of the studies by TNO (Netherlands) and DLR Germany, pertaining to air, road and rail noise and aircraft noise respectively. These studies combined laboratory and field approaches (Basner et al, 2003-2007; Passchier et al, 2002, 2003, 2005, 2007) or applied

laboratory measures in a field setting (to be discussed separately below). According to Hume the discrepancy between field and laboratory studies remains and there is still uncertainty about the long term health consequences of night-time noise disturbance on exposed populations. Epidemiological studies with representative samples of the population are deemed necessary to investigate the association between night-time (aircraft) noise exposure and cardiovascular disease. The issue of increased risk in vulnerable groups including young, old, sleep disorder patients, and shift workers, is frequently mentioned in the literature but rarely studied In particular, the elderly and hospitalized people, deserve more attention. .

3.2 Current evidence

Recent studies with respect to transportation noise and sleep effects is reported in Tables A1 and A2 in the Appendix. These Tables present recent peer-reviewed studies. They are listed chronologically, and separately, for field (field studies are a mix of observational, epidemiological, clinical and field surveys) and laboratory studies. In addition three major studies are presented in Table A3 which were only reported at national levels, with summaries in English.

3.2.1 Results of field studies

The studies discussed in this paragraph pertain to fifteen field studies. As mentioned, these field studies are a broad mix of observational, epidemiological and field experiments. Sample sizes range from 28 to 13557.

Field/rail

A significant association between noise levels expressed in continuous levels or discrete classes of LAeq (outside) and subjective sleep disturbance was found in all three studies (Aasvang, 2008a; 2008b; Bonnefond et al, 2008). Mediating factors were age, type of traffic, type/location bedroom, insulation, noise sensitivity, number of events. Shift workers report sleep disturbance independent of noise level.

Field/road

The findings of field studies including road traffic noise (eleven studies) confirm a positive association between nighttime noise and subjective sleep disturbance in adults (Bjork, 2008; Jakovljevic, et al, 2006; Ohrtrom, 2006) in adults and children (Ohrstrom, 2006). Children were found to sleep better under noisy circumstances, had less awakenings, but a higher level of motility than their parents. Two intervention studies (Ohrstrom, 2004 and Nilsson and Berglund, 2006) were performed, and Ohrstrom reported a considerable improvement of sleep quality after a reduction of noise traffic events at night dropping from 1375 to 180 with an 8 dB(A) drop of LAeq24 from 70 to 62 dB(A). Nilsson and Berglund did not report such a reduction. Ohstrom et al (2006) report the importance of a quiet side to the dwelling, with improvement of sleep, and self reported physiological and psychological wellbeing. Bjork (2008) reports a significant association between noise exposure levels and concentration and self reported treatment for hypertension only in the highly annoyed group. Results from the Hyena study (Harabilis et al, 2008) show a positive association between LAeq and L_{MAX} and bloodpressure level for both air and road traffic noise, independent of the source. Maschke (2005) reported an increased prevalence of hypertension in relation to night time exposure levels (either via sleep or directly). No effect was established on indicators of mental health Non acoustical factors that have come forward from these studies (but unfortunately have not been measured systematically) are gender, ethnicity, unemployment, financial problems, community size, noise sensitivity, neuroticism, location of the bedroom. Worthwhile mentioning is the finding of Ohrstrom et al (2004) that questionnaires on sleep disturbance and sleep logs show similar findings.

Field/air

The limited number of field studies regarding aircraft noise (four in total) show a significant association between aircraft noise exposure and bloodpressure (Harabilis, 2008), prevalence of hypertension (Kim et al, 2008), prevalence of insomnia (Kim, 2008) after adjustment for relevant demographic variables, and perceived sleep disturbance (Quehl, 2007, 2008) and nighttime annoyance, but not for the number of perceived awakenings. A comparison of three noise metrics (LAeq, L_{MAX} and number of events) showed that the number of events is by far the best predictor for all perceived sleep indicators, with a threshold level of 33 dB(A) (Quehl, 2005).

3.2.2 Results of laboratory studies

These include 43 papers on laboratory studies, which were in some cases overlap with the publications on field experiments and sometimes combined sources are reported. This implies that results might be discussed under different sections. Sample sizes lie in the range of 9 to 128 subjects. Again the studies objectives are quite diverse at the cost of comparability.

Lab/rail

Six of the studies focused on rail noise, be it exclusively or in combination with other sources. Most rail-noise-related experiments included EEG related measures as key outcome variables (Campbell et al, 2005; Griefahn et al, 2004; Marks et al, 2006; Saremi et al, 2008; and Schaphin et al, 2009), either in combination with subjective measures of sleep disturbance and /or performance indicators. The study of Graham et al (2009) was focused on cardiac indices and Michaud et al (2009) included saliva samples to study hormonal effects of nighttime rail noise. A systematic effect on subjective measures is reported, but EEG measures were less reactive when related to LAeq. Griefahn et al (2004) concluded that nighttime intermittent sounds are most disturbing, irrespective of noise source. Marks et al (2006) found a gradual decrease of sleeping quality and reaction time, EEG related indices at all levels, and a strongest reaction to rail noise. Campbell interprets these effects as adaptive/protective processes against obtrusive sounds. Saremi's et al (2008) study sheds light on the importance of sleep stage and reported an arousal effect in REM and especially in stage 2. The type of train (passenger versus freight) was an important mediator. In contrast to what was found by others (see e.g. Marks et al, 2006). Schapkin only found a noise effect on EEG indices but not on subjective measures nor performance, while both using the same noise metric (LAeq). Task difficulty and perceived sleep quality come forward as important moderators.

Lab/road

With a few exceptions, most studies (fourteen papers) on road traffic noise and sleep effects included EEG measures in combination with subjective measures, and or performance measures. The study of Graham et al (2009) was focused on cardiac indices. Griefahn et al (2008) also included HR as an outcome variable and both papers of Skanberg and Ohstrom (2004) refer to motility as the key outcome variable Sasazawa (2004) performed an epidemiological study on 59 women. Habituation of subjective measures, but not of physiological measures, was reported by Griefahn et al (2008) and Kurioana (2002).

Ohrstrom and Skanberg and Skanberg (2004) reported a noise effect on subjective measures but not on motility. The effects were comparable in the lab and field. Marks et al (2008) report an increase in awakenings due to L_{MAX}, the duration as well as the intervals between noise events, especially during REM and the second part of the night. Graham et al (2009) found cardiac noise effects to road traffic noise indicative of parasympathetic withdrawal. Griefahn (2008) points out that a change in HR might be a response to awakening and not a noise effect per se. Schapkin et al (2006) found a noise effect on EEG indices as well as on subjective measures but not on performance, as has been found by others. The effect was the most pronounced in people with an a priori sleeping disorder.

Lab/air

Twenty four publications pertain to laboratory studies into the nighttime noise effect of aircrafts on sleep. Five studies report the use polysomnographs, or EEG measures, three were aimed at sleep structure, and four included cardiac reactions. Only one study measured motility (Brink et al, 2008) and another one papillary unrest (Basner, 2008). Subjective measures and performance were also examined in several studies, in combination with other outcomes.

Regarding cardiovascular effects, results show systematic cardiac reactions with increased levels of noise exposure. Aydin et al (2007) reports higher BP levels with noise levels above 50 dB(A) . The example of Aydin concerns a controlled experiment comparing take off areas and non take off areas around Frankfurt airport in “normal groups”. BP responses were found at LAeq levels of 50 db outside, which is applicable in 3/4 of the time. These effects were not found in the control group. At the same time subjective effects were found in the control group, but not in the exposure group. No mention has been made about noise sensitivity in this paper. Carter (2002) finds HR and BP effects but each to different aspects of noise (level versus sudden onset) and in relation to EEG awakenings indicative of increased Carter (2002) finds HR and BP effects but each to different aspects of noise (level versus sudden onset) and in relation to EEG awakenings indicative of increased sympathetic activity, which is in contrast with findings of Graham et al (2009) who find no increase in sympathetic activity but parasympathetic withdrawal. An association was found between noise exposure (L_{MAX}) levels and cardiac reactions. Basner et al (2008) report similar results to Carter: an association was found between noise exposure (L_{MAX}) levels and cardiac reactions. If spontaneous awakenings were accounted for the curve is comparable to EEG measures. A recent experiment of Basner et al and re-analysis of the DLR data (2006, 2007, 2008) show a differential effect of noise on different sleep indicators: EEG, arousals, awakenings and sleep stage come forward as the most robust measures. Time awake effects are more pronounced in Stage 2. Earlier analysis (Basner et al, 2005) showed a reduction of SWS and increase of REM, and an effect on total sleep time. Motility effects as measured by Brink et al (2008) also show the strongest effects early in the morning. These effects are also confirmed in the experiments of Marks et al (2007, 2008). The number of awakening has been shown to be less during SWS, but if these occur, the performance effects are significant.
Re. subjective effects: Annoyance reaction (the day after) were confirmed for all noise metrics (by Quehl et al, 2007, 2008), and a combination of SEL, LAeq and L_{MAX} is recommended. Pre-annoyance, gender and rated necessity of aircraft come forward as important moderators. Hormonal effects were only found in the lab and are restricted to increased cortisol levels (Basner et al, 2005, Michaud et al, 2008). Basner (2008) measured pupillary unrest after as an indicator for objective sleepiness. This is the first study to include an objective measure of sleepiness. An increase of response to events and equivalent noise levels was found but did not exceed pathological levels.

3.2.3 Results of three major sleep studies in more detail

As part of the health impact assessment around Schiphol airport commissioned by the Netherlands Ministry of Housing, Spatial Planning and the Environment and in close collaboration with the Netherlands Institute for Public Health and the Environment (RIVM), a study was performed among 415 adults residing at various distances from Schiphol airport. The objective was to derive dose response relationships for night time noise effects and to estimate the prevalence of noise related sleeping disorders at a population level.

The subjects in this study were exposed to usual night-time aircraft noise in their bedroom. Ages varied between 18 and 81 years, 50% of the subjects were male, 6% lived less than 1 year in the present neighbourhood, 44% were over 15 years and the remaining 50% between 1 and 15 years. The study has been carried out at 15 locations within a distance of 20 km from Schiphol. The locations were selected so that there was a variation from relatively few aircraft at night up to the highest exposure in residential areas, close to the airport. At each location, the study took place during two subsequent intervals with 11 nights. To assess night-time (aircraft) noise exposure of subjects, noise measurements were performed from 22– 9h with indoor noise monitors in the bedroom of each subject and with one outdoor noise monitor. The noise monitors stored the equivalent sound level each second. Aircraft noise events were identified by comparing the noise and time data stored in the indoor and outdoor noise monitors with information obtained from the aircraft identification system at Schiphol (FANOMOS). The report presents relationships between night-time aircraft noise exposure and motility for three time scales:

- On the *instantaneous level*: instantaneous (onset of) motility during sleep has been related to L_{MAX} and SEL. The (onset of) motility during 7 15-s intervals has been analysed: the 15-s interval at which the maximum sound level occurs, 2 15-s intervals preceding that interval, and 4 15-s intervals following that interval. Aircraft noise-induced (onset of) motility has been assessed by subtracting from the probability of (onset of) motility during these 15-s intervals the probability of (onset of) motility in 15-s intervals without aircraft noise. Aircraft noise-induced increase in motility is maximal in the 15-s interval with the maximum noise level of the over flight and in the subsequent interval. Aircraft noise-induced increase in onset of motility is, at higher values of Lmax, maximal in the 15-s interval preceding the 15-s interval with the maximum noise level and somewhat less in the 15-s interval with the maximum noise level. No exposure-effect relationships could be derived if descriptors of outdoor aircraft noise were taken as predictors.
- On the level of a **sleep period:** mean motility during a sleep period has been related to the equivalent aircraft sound level in that period. It was shown that mean motility increases with indoor aircraft equivalent sound level. Also, duration of sleep latency time has been related to aircraft equivalent sound level during sleep latency time.
- On a **long-term** basis: mean (onset of) motility over the 11 sleep periods has been related to L_{NIGHT}.

In collaboration with RIVM and commissioned by the Ministry of Housing, Spatial Planning and the Environment in the Netherlands, TNO subsequently performed a field study (Passchier et al, 2007) on the effects of nighttime road and railway noise. 262 subjects participated in the study for six nights and days (1572 subject nights). Twelve locations were selected. Noise monitors measured continuously 1-s sound levels from 22:00 till 9:00 hours outside in the vicinity of the traffic noise source at a location and inside at each of the subjects bedrooms. Subjects wore actimeters to monitor motility during sleep and to register self-reported awakening. A sub-group of 36 subjects (172 subject nights) wore ECG-equipment to monitor IBI (Inter Beat Interval). The data have been analyzed on three time-scales: an instantaneous level (noise event), a level of a sleep period time, and an aggregated level of six sleep period times. The analyses showed that nighttime noise from road and rail traffic adversely effects sleep. The results show a consistent pattern. Motility, motility onset, self-reported awakening, and heart rate increase and reported sleep quality decreases with increasing road and railway noise exposure indoors during sleep. Motility, heart rate and awakening (by means of actimeter), as well as subjective measures of sleep were the key outcome variables. Relevant data was also derived from the so called Schiphol monitor, collecting data over a period of 10 years with a repeated measurement at two moments (2002-2005) and a panel study yearly during this period (Houthuijs, van Wiechen, 2006). A meta-analysis of the GES data (aircraft), the German data on road and rail traffic from Griefahn and the current study show consistent patterns regarding motility. Reactions were much more pronounced for aircraft noise than for rail and road traffic noise: four times as high at Lmax levels range up to 45 dB(A).

A significant association was found for most subjective indicators of sleep quality and bed room noise levels: annoyance at night in bedroom, dissatisfaction with noise, frequency of sleep disturbance. Comparison with the Miedema (figure 4) curve for severe (subjective), sleep disturbance shows that the dose effect relation in this study is highly comparable.

- No association was found for sleep quality and perceived health (SF36).
- An association between awakenings or heart rate, and acute noise exposure, could not be established in this study.
- A linear age effect could not be established for motility: the 45-60 group and people with diagnosed depression seemed to be more at risk.
- Gender differences vary per outcome and are more pronounced in women when awakening reaction is concerned.
- Results regarding heart rate (and variation in heart rate) show acute as well as accumulated effects indicative of cardiac parasympathetic withdrawal during sleep, specifically during the second half of the sleep period. No effect of indoor traffic noise on cardiac sympathetic tone was observed.
- Within the framework of this Working Paper it is important to mention that, although the findings are assumed to be representative and thus transferable, it cannot be excluded that the effects would be different if the living circumstance deviate strongly from those in the Netherlands (for example, in terms of housing quality, background noise levels, sleeping patterns in terms of duration, time of sleep etc etc).

Overall, it is concluded that nighttime noise exposure from road and rail traffic has adverse effects on sleep. An increase in road and rail traffic noise (in the bedroom) is associated with increased motility, heart rate and perceived sleep disturbance. Only a direct relation was established between acute passages and motility and a dose response relation could be established.

In the period between 1999-2003 DLR Institute of Aerospace Medicine conducted investigations (Basner et al, 2004) on human effects of nocturnal aircraft noise. 128 subjects were studied in the laboratory during 13 nights from 11 PM to 7 AM, with max levels of 45-80 and 4-128 aircraft movements. A broad range of physiological measures was performed including EEG, EMG, EKG, finger pulse amplitude, movements, actimetry, hormone levels derived from urine samples and a range of psychological measures including annoyance, fatigue, mood, performance, subjective sleep quality, and computer-assisted performance tests.

In the field study 64 people were studied for nine nights. Subjects did not suffer from sleep disorders and had normal hearing. Outdoor noise levels ranged from 35-87 and a maximum level of 64 dB(A). Inside the home: 20-73, 44 max. LAeq levels were 54 outdoor and 36 indoor. The difference between outdoor and indoor was 28 with window closed, 18 with window tilted and 13 with window open.

Major findings:

- Effect on % highly annoyed, but not on mood, fatigue, stress and recuperation
- No effect on stress hormones (adrenaline and noradrenaline)
- Effect on cortisol levels but only in laboratory setting
- Sleep time difference two minutes compared to quiet night
- Effect on sleep structure SWS reduced and REM increased
- Threshold levels in field for EEG awakenings was 33
- In laboratory, above 45, no threshold levels for awakenings
- Based on the findings, precise doe response curves could be derived for awakenings
- A prognostic model was derived which could be (and has been) applied near other airports
- Further criteria can now be developed, e.g. (number of awakenings per unit of increase in dB(A)

Strength of evidence: a summary

Table 4: Summary overview of noise effects on sleep disturbance in adults

Effect	**Evidence** [a]	**Situation**[b]	**Threshold value**		
			Noise metric	dB(A)	Indoor/ Outdoor/[c]
Sleepdisturbance					
Changes in EEG parameters	sufficient[d]	Sleep	SEL	35	Indoor
awakenings	sufficient	Sleep	SEL	60	Indoor
(onset of) motility	sufficient	Sleep	SEL	35-40	Indoor
subjective sleep quality	sufficient	Sleep	L_{NIGHT}	45[e]	Outdoor
heart rate	sufficient	Sleep	SEL	40	Indoor
mood	limited	Sleep	LAeq, 06-22h	>60	Outdoor
hormone levels	inadequate	Sleep			
immune system	limited	Sleep			
task performance next day	limited	Sleep			

a classification of evidence (HCN, 2004)
b situation= during sleep
c Indoor/Outdoor difference 15-25 dB(A) for homes with single glazing
d Threshold transport noise
e Threshold for severe disturbance

3.3. Exposure related issues

The effects of transportation noises have been studied most frequently. Here we focus on transport related noise from road traffic, rail and aircraft noise.

Noise metrics

Noise induced sleep disturbance is assumed to lead to short- and long-term consequences for performance, well-being and health. It is therefore important to assess the impact of noise exposure on sleep at a population level (Basner and Griefahn, 2009). Different indices have been used to describe noise-exposure[1] and there is no general agreement on which should be preferred among the various available noise indices (Muzet, 2002; Finegold et al, 2007). The choice of noise metrics for establishing exposure criteria depends on both the particular type of noise source and the particular effect being studied. Indices can be subdivided in integrated energy indices (LAeq, L_{DEN}, L_{NIGHT},…), statistical indices (L10, L50,…) or event based indices (LA_{MAX}, Sound Exposure Level: SEL, Number of Noise Events: NNE,…)2. As we shall see later, it is difficult to correlate night time noise exposure defined by integrated indices with actual sleep disturbance. These indices, which give a good overall description of global noise exposure, are much better for daytime or 24-hour exposure, while event indices would be more appropriate to predict sleep disturbance. Large review of the literature shows that it is generally acknowledged that measures of peak sound level are better predictors of disturbances in sleep than measures of average sound level (Berglund et al, 1999; Hofman, 1994). However Pearsons et al (1998) showed that, overall, sound exposure level (SEL) was a better predictor of sleep disturbance across the various studies included in their meta-analysis than was the maximum frequency–weighted sound pressure level (L_{MAX}) (Finegold et al, 2007). The community noise guidelines recently published by the World Health Organization (WHO, 2009) allow the use of either L_{MAX} or SEL. Thus, there is still no consensus on the best metric to use. The review of recent studies makes it again very clear that the fitness of the metric used is highly dependent on the effect measured. Overall it seems that integrated measures as L_{NIGHT}/LAeq are associated with subjective measures of sleep disturbance, motility and long term CVD effects and much less with acute effects and physiological changes. The EC commission (2004) and WHO (2009) advised on the use of L_{NIGHT} as the primary indicator for sleep disturbance (see also position paper TNO, 2003). L_{NIGHT} can be linked to subjective measures but could also be linked to the number of extra awakenings due to nighttime noise (Basner et al, 2008) and motility (Passchier, 2002, 2007). Since many indicators of sleep are more related to the acoustic properties of single-events number of events it is considered to be more advantageous to use maximum sound pressure levels L_{MAX} or sound exposure level (SEL) as supplementary noise indicators for night period protection (as proposed in END) (Basner, et al, 2005-2008; Berglund, 1999).

It is generally recognized that outdoor nighttime noise exposure at the most exposed façade of a dwelling (in terms of L_{NIGHT}) is not the only acoustical factor that influences sleep disturbance. Therefore, attention is also being given to the role of the actual noise exposure at the façade of the bedroom and the difference between outdoor and indoor noise levels (sound insulation) of bedrooms. The combination of metrics (L_{NIGHT}, L_{MAX}, SEL, and particularly the number of events (NNE) has been recommended in several papers.

[1] For an overview of the indices we refer to the working paper of Prof. AL Brown (annoyance)
[2] For an overview of conversion methods we refer to the EC position document (2004)

Effects of changes of noise exposure – (Brown and van Kamp 2009b)
Relatively few community studies assessing the impact of noise reduction on sleep have been conducted. Those studies that have been carried out with a reduction between 6-14 dB(A) resulted in both subjective and objective improvement in sleep (Stansfield et al, 2001) However, findings regarding the effects of an increase in noise show that, while a systematic excess response to changes in noise is found for annoyance, such a reaction was not found for activity disturbance including self reported sleep disturbance (Klæboe et al, 1998; Babisch and Eberhardt, 1986; Breugelmans et al, 2007) also found no excess response in sleep disturbance, despite a large excess response in annoyance. However Öhrström (2004) reports good correlations between reductions in annoyance scores and reductions in activity disturbances in her longitudinal study of a large decrease in road traffic noise exposure. Fidell et al (1996) studied the effects of a temporary change around an airport (shutting and reopening the airport) on behavioural awakenings and report no change effect. However, the change was more gradual and one does only expect an excess response to step changes.

A change of at least 3 dB(A) is generally seen as a prerequisite for an effect on annoyance and sleep disturbance to occur. In general it can be concluded that sleep disturbance is less sensitive to (small) changes in noise levels than annoyance, but based on the few studies addressing this topic it is concluded that considerable reductions in noise levels can lead to an improvement in both subjective and objective indicators sleep disturbance.

3.4 Exposure effect relationships

Experimental studies have shown clear exposure-response relationships between single noise events and arousals, awakenings or body movements (Finegold, 2007; Basner, 2006; Marks et al, 2008; Passchier, 2002 and 2007). Exposure-response relationships between L_{NIGHT} or similar integrated measures and sleep disturbances (e.g. motility) have been reported by Miedema et al, 2007) regarding subjective sleep disturbance, mean motility (Passchier et al, 2007) and annoyance the next day (Quehl et al, 2006). Event related measures are related to acute effects while L_{NIGHT} as a whole night indicator is more suitable for the prediction of overall sleep parameters.

EEG related arousals come forward in recent studies as the best predictor of sleep disturbance, but as we saw earlier there are some other indicators as well for which a firm dose response relationship was established. There is no agreement on what exposure response relation should be applied. Part of the problem might lie in the fact that it is still unclear what would be the best predictor of long term health effects. Since objective and subjective measures clearly do not converge, the long term effects would not be protected by solely using a dose response for whole sleep indices such as subjective disturbance, annoyance and mean motility. The review of recent studies has given more insight into the role of awakenings related to cardiac reactions, and sleep fragmentation which might be the key to understanding long term health effects and cognitive effects (e.g. memory) especially in vulnerable groups. According to Berry and Flindell (2009) at the moment no reliable dose-response relationship exists for noise and sleep disturbed related health effects that could be used for policy purposes. Application of dose response curves derived from field and laboratory studies is further hindered by the fact that there is large individual variation. Aspects that are of influence such as noise sensitivity, poor genetic sleeping quality, shiftwork, age, etc are usually not taken into account in the curves presented in the literature.

At the moment the generalized curve of Miedema, based on epidemiological studies, appears the best available. However limitations discussed above should be borne in mind when applying this curve.

In the framework of this working paper we are primarily interested in the effects of long-term traffic noise exposure (expressed in L_{NIGHT}) on health and well-being. Several effects with sufficient evidence for a long term association with traffic noise were identified: insomnia, sleep disturbance, sleep quality and motility. From existing evidence it is not possible to derive an exposure-response relation for (perceived) sleep quality due to lack of standardized questions. Only a few studies have investigated the association between night time noise exposure from road traffic and insomnia (Kawada et al, 2003; Passchier-Vermeer et al, 2007). The results of these studies are inconsistent and no dose response curve can be established. Miedema and Vos (1998; 2003; 2007) presented source specific curves for annoyance and sleep disturbance and made use of the data of 20 noise surveys (including 34,214 respondents) published between 1965 and 1992 from different European countries, Australia, USA and Canada. For road traffic noise, 21,228 data-points, derived from 26 studies (1971-1994 from different European countries and Canada) were available. For railway noise only nine studies were available, published in France, Germany, the Netherlands, Sweden and the UK between 1972 and 1993. In order to derive exposure-effect-relationships, the authors made use of both the ordinary least squares regression and multilevel procedure. Later, Miedema re-analysed the data adding four studies. The relations are presented in table 4 and give the percentage of highly sleep disturbed (%HSD), per noise source as a function of the outdoor L_{NIGHT} at the most exposed façade (Miedema et al, 2003 and 2007).

Table 5: Dose response curves for road, rail and air and subjective sleep disturbance

End point	**Applicable Range**	**Formula**	**Reference**
High Sleep Disturbance Road	L_{NIGHT} † ‡§ 45 – 65 dB(A)	$\%HSD = 20.8 - 1.05L_{NIGHT} + 0.01486 \times L_{NIGHT}^2$	Miedema et al, 2007
High Sleep Disturbance Rail	L_{NIGHT} † ‡§ 45 – 65 dB(A)	$\%HSD = 11.3 - 0.55L_{NIGHT} + 0.00759\ L_{NIGHT}^2$	Miedema et al, 2007
High Sleep Disturbance Air	L_{NIGHT} † ‡§ 45 – 65 dB(A)	$\%HSD = 18.147 - 0.956L_{NIGHT} + 0.01482\ L_{NIGHT}^2$	Miedema et al, 2007

† L_{NIGHT}: the equivalent sound level over night-time (11 pm to 7 am).
‡ these are outdoor noise exposure levels of the most exposed façade.
§ these are outdoor noise exposure levels.
** the applicable range could pose a problem for application in countries/cities with high max noise levels

In Figure 4 the results of the 2003 meta-analysis are presented for road and rail-traffic noise. It shows the curves for three sleep disturbance measures (%High Sleep Disturbance (HSD)), % Sleep Disturbance (SD), and % -,Low Sleep disturbance (LSD) and their 95% confidence intervals, together with the polynomial approximations of the curves. The curves are based on data in the L_{NIGHT} range 45-65 dB(A). For functions see Appendix IV. For an overview of available exposure effect curves for the other sleep related effects we refer to EC (2004); WHO (2009); Passchier et al (2003); Finegold (2007); Flindell, I.H. & McKenzie, A.R. (2000).

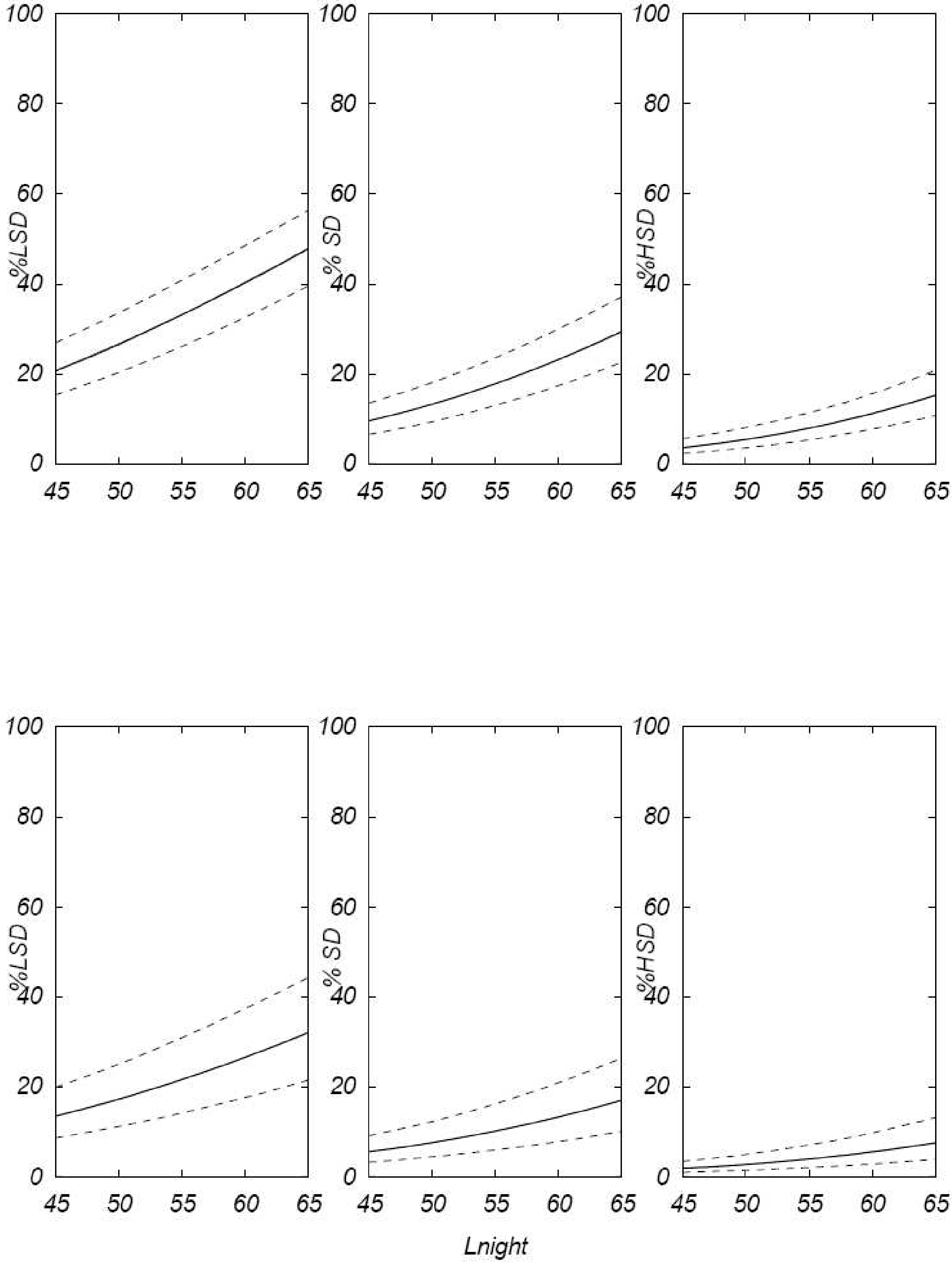

Figure 4: The relationships between L_{NIGHT} (outside at most exposed façade) and three sleep disturbance measures (%HSD, %SD and %LSD) (solid lines), their 95% confidence intervals (broken lines), and the polynomial approximations of the curves for road traffic (upper row) and railway (bottom row)

3.5 Transferability of dose response relationships

Generalized exposure-effect estimates are often used to estimate impacts in another population/area or country as part of a risk or health impact assessment. Such assessments assume that the available exposure effect estimates are transferable. Requirement for such applications is that the source and target populations are similar with regard to factors that influence the magnitude of the exposure-effect estimate. The basic health status, demographic structure, morbidity structure, traffic composition and noise characteristics are examples of these factors (see e.g. Krzyzanowski et al, 2002; van Kempen et al, 2005). For sleep disturbance, the generalizability of exposure-effect curves to different countries and different areas has not yet been well established. Complicating this is that situational and personal aspects play a role. It is, for example, possible that there are substantial differences in terms of susceptibility to noise between the source and target population. The relation between noise and sleep disturbance might deviate from the established curves because of cultural differences in sleep behaviour, acceptance of transportation noise exposure, differences in climate and the adequacy of housing, sound insulation techniques and ventilation behaviour (Staatsen et al, 2004; Franssen and Kwekkeboom, 2003). Much depends on the extent to which a variety of inherent and acquired personal factors interact with environmental factors (HCN, 2004).

The generalized relationships as described above refer to the perceived disturbance by nighttime noise – and it should be recognized that this is different from sleep quality. They are based on studies in adults and it is not clear whether they could be applied to other age groups such as children or the elderly. Moreover, results of field studies and laboratory studies are different (see above) It is therefore advisable to only use generalized curves based on field studies, and do this with caution, to estimate the impact in a different population.

Ideally the potential confounders and mediating factors and effect modifiers of both populations as described above should be compared before a valid estimation of the impact, (in this case sleep disturbance) of transport related noise in HK can be made.

3.6 WHO noise guidelines values for sleep

Based on the evidence of the health effects of night noise, and an overall summary of the relation between night noise levels and health effects, the draft NNGL of WHO presented stepwise guideline values in relation to the different effects on sleep. These threshold or better target values are extremely important for future policies regarding nighttime noise exposure and for defining areas and locations at risk regarding levels of night time exposures. Table 6 summarizes the effects and their accompanying target values in a stepwise way. Starting at the bottom, the table shows that above 55 dB cardiovascular effects become the dominant effect, which is thought to be less dependent on the nature of the noise. In the range L_{NIGHT}, outside from 30 to 55 dB, the impact is assumed to be more dependent on the exact circumstances. The literature showed that a number of acute sleep effects are related to threshold levels expressed in LA_{MAX}. What the health relevance of these effects is cannot be easily established. It is assumed, however, that an increase in the number of such effects over the base line may constitute a sub-clinical adverse health effect. For the primary prevention of sub-clinical adverse health effects in the population related to night noise, it is recommended that the population should not be exposed to night noise levels greater than 30 dB of L_{NIGHT}, outside during the night. Therefore, L_{NIGHT}, outside 40 dB is the ultimate target of Night Noise Guideline (NNGL) to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly, from the adverse health effects of night noise

Table 6: Summary of the relation between night noise and health effects in the population

$L_{night,outside}$ **up to 30 dB**	Although individual sensitivities and circumstances differ, it appears that up to this level no substantial biological effects are observed.
$L_{night,outside}$ of **30 to 40 dB**	A number of effects are observed to increase: body movements, awakening, self-reported sleep disturbance, arousals. With the intensity of the effect depending on the nature of the source and on the number of events, even in the worst cases the effects seem modest. It cannot be ruled out that vulnerable groups (for example children, the chronically ill and the elderly) are affected to some degree.
$L_{night,outside}$ of **40 to 55 dB**	There is a sharp increase in adverse health effects, and many of the exposed population are now affected and have to adapt their lives to cope with the noise. Vulnerable groups are now severely affected.
$L_{night,outside}$ of **above 55 dB**	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a high percentage of the population is highly annoyed and there is some limited evidence that the cardiovascular system is coming under stress.

An interim target value is proposed for countries where short term achievement of the NNGL values is not feasible for various reasons, and where policy-makers choose to adopt a stepwise approach at the local or national levels.

Night noise guideline (NNG) Interim target (IT)	$L_{night, outside}$ = 40 dB $L_{night, outside}$ = 55 dB	**Recommended night noise guidelines for Europe**

In the NNGL all countries are encouraged to reduce gradually the size of the population exposed to levels to 40 dB of L_{NIGHT}, (NNG) outside over the interim target value 55 dB of L_{NIGHT}, outside (IT), as effectively as possible. It is highly recommended to carry out risk assessment and management activities at national level targeting the exposed population, and aiming at reducing night noise to the level below IT can be used for health impact assessment of new projects (e.g., highways, railways, airports or new residential areas) even before the achievement of NNG, as well as for the risk assessment of the whole population. In the long run the NNGL would be best achieved by control measures on the sources along with other comprehensive approaches.

4. Conclusions

Sleep is a biological necessity, and disturbed sleep is associated with a number of adverse impacts on health. Sleep is also an essential part of human functioning and is recognized as a fundamental right under the European Convention on Human Rights (Article 8.1). Sleep disturbance can thus be considered as one of the main aversive effects of nighttime exposure to transport noise and protection against this can only be achieved by setting limit values for nighttime noise levels on top of the existing policies which are primarily based on daytime levels and noise annoyance.

There is sufficient evidence that nighttime transport noise leads to acute effects such as physiological response, arousal, awakening, sleep stage changes, and the amount of total sleep. It also leads to after effects such as self reported sleep disturbance, reduced performance in the daytime and cognitive effects. However, what the long term health effects at cognitive, physiological, emotional level and behavioural level (performance) are of these instantaneous and short term effects of noise on sleep, is still unclear and hypothetical. Habituation was found in several laboratory studies but, due to unrealistic noise exposure characterization, these findings might not be applicable to real life situations. This might indicate that the time interval between two noise events also has an important influence on the probability of obtaining a response. Moreover, evidence on habituation is restricted to awakenings but not available for physiological, perceived quality and other after effects. The autonomic responses do not habituate. We still lack evidence regarding the long term effects of instantaneous sleep-disturbances but more recently there is evidence of increased risk of diabetes due to sleep disturbance (Donga et al, 2010).

According to the WHO, there is nevertheless consensus about the biological plausibility that short term sleep disturbances form a long term health risk. There is sufficient evidence that chronic sleep disturbance is related to self reported overall sleep disturbance, insomnia-like symptoms, as well as increased medication use. For CVD type effects and depression (and other diseases) no such relation can be established based on current evidence. However, in particular night time noise exposure is considered to be a risk factor for CVD (see e.g. Maschke, 1992; HCN, 2004).

In general it has been found that laboratory studies and field studies produce divergent results, and this appears to be related to aspects of habituation or aspects of the noise exposure itself. There is also a systematic difference between results on subjective and objective outcomes, which sometimes seem to be contradictory, but there is growing insight that these have to be considered as separate aspects of the sleeping process. Subjective responses have been found to habituate, whereas physiological responses do not show adaptation. So even if an individual does not report subjective disturbance of the sleep or night time noise annoyance, this does not exclude that the individual is experiencing physiological reactions. These persistent physiological responses to night time noise might have more detrimental effects in the long term than subjective effects, although chronic subjective sleep disturbance might, via stress processes, lead to more serious health problems in their own right.

There has been an ongoing debate regarding the appropriate noise metric to be used to assess sleep disturbance. From current evidence it is clear that different indicators of sleep disturbance are related to different noise metrics and a combination of LAeq, L_{MAX} and SEL is preferable. An association between LAeq and L_{NIGHT} has been established for subjective sleep disturbance, motility and awakenings, whereas single event levels, L_{MAX} and the number of events (combined with levels) are more predictive of instantaneous and short term effects of arousal, cardiovascular responses, sleep stage shifts etc.

Current evidence has shown that some effects are not a “real” noise effect but a by-product of sleep stage shifts, as is the case for performance related cognitive effects, or blood pressure and heart rate responses. The latter have been found to be an effect of awakenings rather than a direct noise effect.

Although recent studies have considerably increased insight into the mechanisms that play a role in noise sleep effects, the step from these findings to assessing impact at the population level, and defining the key information needed to derive these impacts, is still a tenuous one. Despite these uncertainties, current policies and guidelines, as published by the EC Commission and the World Health Organisation, have suggested standards for the noise metrics for sleep disturbance, the sleep effects to consider, the dose response relationships to apply and the threshold levels to be used in preparing nighttime noise policies. Threshold levels, L_{NIGHT}, outdoors have been proposed ranging from:

- 30 dB(A) of no effect,
- 30-40 dB(A) some effects, but within acceptable limits, except for vulnerable groups,
- 40-50 dB(A) where the effects are considerably increased and for vulnerable groups one could speak of severe effects, and
- Over 55 dB(A) where one could speak of a serious public health problem, with potential cardiovascular risk.

There is no evidence as to whether the limits are applicable to other countries, and specifically to Asia[3]. Studies from Asia are scarce and studies which have been reported (e.g. from Korea or Japan) were strongly epidemiologically oriented. However there is no reason to assume racial or cultural differences in adaptation of reactions like awakenings, motility and CV reactions during sleep. A clear distinction is therefore be made between annoyance during night and other, more objective sleep indicators. The NNGL is only recently published and their adoption is still being considered. WHO recognises that these limit values might not be realistic to achieve in many places in the world, when noise levels are considerably higher and has therefore formulated an interim target value of 55 dB (L_{NIGHT}, outdoor).

The various dose response relations were primarily derived from EU and USA studies. Differences could include factors such as background noise levels and housing differences, but also social differences (e.g. cultural differences in noise sensitivity, or in sleeping patterns in terms of duration of hours of being asleep.

From the current literature, several of these so called non-acoustical factors have been studied, but not in a systematic way, and the evidence often remains anecdotal and highly

[3] The NNGL are based on International evidence but includes few studies from Asia. The NNGL might indeed not be feasible in HK but it is still not expected that objective sleep responses might be very different across cultures. Regarding. subjective reactions this might be true indeed. There is a dilemma here: while objective measures are better indicators for sleep disturbance the evidence is primarily on acute effects, while it is not known yet what the long term effects are. On the other hand subjective sleep disturbance is such a chronic effect (which is well related to L_{NIGHT}) but this effect seems to habituate and it is unknown whether these effects are culture sensitive.

dependent on the particular composition of the population being studied. In laboratory studies these aspects are controlled, but at the price of ecological validity.

It is in this realm that the studies performed in the past eight years, combining field and laboratory approaches and including larger samples and more heterogeneous groups of participants in their normal living environment, have made the largest contribution.

Vulnerable groups identified in the literature include the: elderly, children, shift workers, pregnant women, people with a sleeping disorder, and the chronically ill—each with their specific risk factors. For example, it has been shown that shift workers have effects across all noise levels. Children score better on awakening and subjective sleep disturbance but show a higher level of motility than adults. Since they are in a vulnerable period with regards to development and learning, the effects, at a cognitive level, of a disturbed sleep such as sleep stage shifts, might be much larger in children than is the case for adults.

Summing up these new findings and in view of the limitations of the evidence of noise induced sleep disturbance until 2002, it can be concluded that the noise and sleep field has definitely progressed but as shown above, there is still ongoing debate on what effects need to be taken into account when applying these findings at a population level, which threshold levels should be used, and which generalized exposure response relationships should be used. Another limitation of particular importance in the context of this working paper is the primarily Western Europe orientation of sleep research and thus the limited base of these findings. However, sleep researchers are of the opinion that the basic physiology of sleep, and sleep disturbance by noise, may not be different across cultures. A large cross cultural study, which would apply the same methods in different parts of the world, would be necessary to fill in this knowledge gap. This also applies to the specific situation in HK with higher densities and primarily high rise buildings. A first step in that direction would be to estimate the number of people affected by transport noise in Hong Kong in terms of sleep disturbance by means of a Health Impact Assessment (HIA). For such an exercise to be valuable, more information about the HK conditions, in terms of car fleet, types of rail system, proximity to major airports, noise load and number of people exposed to different levels, housing stock, demographics and sleeping patterns etc would be essential.

Noise policies in Hong Kong are currently based on annoyance. This does not necessarily protect sleep and additional limit values for night time noise are, in line with WHO, are recommended. The WHO target values for nighttime noise might be a good instrument for this. Although L_{MAX} and SEL are important noise indices in relation to acute noise effects during sleep, L_{DEN} and L_{NIGHT} are proposed as suitable noise metrics, providing a considerable degree of protection against noise during sleep, in line with the current recommendations of the European Commission, The Health Council Netherlands and the WHO. L_{NIGHT} level ties the LA_{MAX} related effects to a maximum and therefore allows for a protective/conservative approach. Subjective sleep disturbance is hereby a suitable indicator and possibly being more predictive of long term effects than instantaneous effects as arousals and motility. The planned survey in Hong Kong will provide important data for this, including data regarding subjective sleep quality, sleep disturbance per source and sleep annoyance during the night as well as important demographics and confounding factors. The application of the NNGL for HK is a matter of consideration of the relevant authorities. From the HK survey both self reported sleep disturbance and night time annoyance will be available as well as a scale re. sleeping quality and medication use regarding sleep. Especially the latter will shed more light on the extent of the problem in HK. If we have the noise data available we can check if there are major deviations of the dose response curves which are available from international studies. Noise policies and limit values are economic and political decisions which are beyond the scope of this scientific review. WHO recognises that there are practical limits in implementing the guidelines.

Large and longitudinal epidemiological studies with representative samples of the population are seen as necessary to further the field regarding the association between night-time (aircraft) noise exposure and cardiovascular disease/ long term health effects.

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Appendix I: Field studies

#	Author	Title	Year	Subjects	Exposure source and Measurement	Outcome	Results
1	Aasvang GM Engdahl B Rothschild K	Annoyance and self-reported sleep disturbances due to structurally radiated noise from railway tunnels	2008a	521	Rail/L_{MAX}, 32 dB(A) limit	Self-reported sleepdisturbance	Significantly related Freight trains and insulation were important effect modifiers
2	Aasvang GM Moum T Engdahl B	Self-reported sleep disturbances due to railway noise: exposure-response relationships for nighttime equivalent and maximum noise levels.	2008b	1349	Rail LAeq and L_{MAX} Type of bedroom and NS	Self-reported sleepdisturbance	Increase of self reported sleep problems with LAeq and L_{MAX} raises type of bedroom and number of events were significant factors, in highest f noise levels. Effect of use of bedroom at most exposed or quiet side should be accounted for.
3	Bjork J Ardo J Stroh E Lovkvist H Ostergren PO Albin M	Road traffic noise in southern Sweden and its relation to annoyance, disturbance of daily activities and health	2007	13557	Road L_{MAX} and LAeq (GIS based)	Sleepdisturbance Annoyance, general health, stress, treated hypertension	No direct association between noise and subjective. health. Significant association between noise and sleep disturbance at highest noise levels. In the highly annoyed group (n=623) also an association with concentration and treatment hypertension Gender ethnicity, unemployment and financial problems important mediators.

#	Author	Title	Year	Subjects	Exposure source and Measurement	Outcome	Results
4	Bonnefond A Saremi M Rohmer O Hoeft A Eschenlauer A Eschenlauer R Muzet A Tassi P	Effects of nocturnal railway noise on subjective ratings of sleep and subsequent cognitive performance	2008	38 day vs shiftworkers young vs middle aged	Rail quiet night, 40, 50 dB(A) during one night	Subjective sleep disturbance and cognitive performance	Young subjects score lower on sleep quality, shift worker rating independent of noise condition, effects on cognitive performance weak. Exception increased reaction time after 40 dB(A) night
5	Basner M Samel A Isermann U	Aircraft noise effects on sleep: application of the results of a large polysomnographic field study.	2006	Na	Air	Na	Protection Zones around airports Less than 1 extra awakening 2. no recall awakening 3. interference at onset as low as possible
6	Haralabidis AS Dimakopoulou K Vigna-Taglianti F Giampaolo M Borgini A Dudley ML Pershagen G Bluhm G Houthuijs D Babisch W Velonakis M Katsouyanni K Jarup L	Acute effects of night-time noise exposure on blood pressure in populations living near airports	2008	140	Air and Road LAeq and L_{MAX}	BP and HR during sleep	BP in relation to events, effect independent of source

#	Author	Title	Year	Subjects	Exposure source and Measurement	Outcome	Results
7	Jakovljevic B Belojevic G Paunovic K Stojanov V	Road traffic noise and sleep disturbances in an urban population: cross-sectional study.	2006	310 119 exposed rest quiet condition	Road LAeq .> 65 and < 55	Subjective measures	Respondents form noisy area report problems with falling asleep, time to fall asleep, wakening and falling back to sleep, closed window and fatigue, also after control for NS and neuroticism NS and annoyance and neuroticism related to most sleep indicators inclusive medication use
8	Kim H Roh S Kwon HJ Paik KC Rhee MY Jeong JY Lim MH Koo MJ Kim CH Kim HY Lim JH Kim DH. EPI	Study on the health status of the residents near military airbases in Korea	2008	917	Air High/low	Medical status	Increased prevalence of insomnia in high exposed group (OR 4.04 for helicopter noise, OR 1.23 for intermediate levels of fighter noise and 4.99 for high exposed to fighter noise, after adjustment for age, sex agricultural noise and occupation) As well as a range of other disease (incl. hypertension and anxiety disorder)
9	Michaud DS Keith SE McMurchy D	Annoyance and disturbance of daily activities from road traffic noise in Canada.	2008	2565 15+	Road	Annoyance and sleep disturbance	High correlation between annoyance and sleep disturbance Annoyance statistically significant associated with sex, age, educational level and community size

#	Author	Title	Year	Subjects	Exposure source and Measurement	Outcome	Results
10	Maschke C Hecht K	Day-night differences in the multifactorial genesis of noise-induced illnesses - Results of an epidemiological study	2005	1718	Noise load at façade, L_{NIGHT}	Prevalence of treatment for hypertension and mental health EPI	Increased prevalence of hypertension in relation to night time exposure levels (either via sleep or directly) No effect on indicator of mental health
12	Ohrstrom E Hadzibajramovic E Holmes M Svensson H	Effects of road traffic noise on sleep: Studies on children and adults.	2006	160 children 160 parents 80/80 in experimental condition	Road/varying levels	Sleep quality, awakenings, windows closed, interference, sleepiness	Children better perceived quality and less awakenings, but higher on motility
11	Ohrstrom E	Longitudinal surveys on effects of changes in road traffic noise: effects on sleep assessed by general questionnaires and 3-day sleep logs	2004	unknown	Road Decrease of number of vehicles from 25000 to 2400 and 1375 to 180 per night	Sleep quality Sleep logs	Sleep quality improved after change Questionnaires and logs show comparable results
12	Pirrera S De Valck E Cluydts R	Nocturnal road traffic noise and sleep quality habituation effects assessed in a test retest field situation	2009		Road		

#	Author	Title	Year	Subjects	Exposure source and Measurement	Outcome	Results
13	Pirrera S De Valck E Cluydts R	Sleep an road traffic noise day by day variability in actigraphic recordings and sleep diaries	2008		Road		
14	Quehl J	Nocturnal aircraft noise, annoyance, and sleep sensation	2005	128	Air Comparison of L_{MAX}, number of events Laeq	Questionnaire data on annoyance, sleep quantity and quality, awakenings and fatigue	Main effect for all three noise metrics, r L_{MAX} only related to annoyance Doubling nr of events > 4 and > 8 increased annoyance and increased subjective sleep disturbance But not for perceived nr of awakenings So nr of events more important tan L_{MAX}, LAeq showed threshold level of 33 dB(A)
15	Nilsson ME Berglund B	Noise annoyance and activity disturbance before and after the erection of a roadside noise barrier.	2006	Not mentioned in abstract	Road reduction from 70-62 dB(A) (L_{DEN})	Annoyance, disturbance of activity including sleep	Up to 100 mt distance annoyance and communication outdoors improved, No effect on sleep and communication indoors Exposure response curves might only be applicable to indoor

#	Author	Title	Year	Subjects	Exposure source and Measurement	Outcome	Results
16	Ohrstrom E Skanberg A Svensson H Gidlof-Gunnarson A	Effects of road traffic noise and the benefit of access to quietness	2006	976	Road LAeq 45-68 dB(A)	Questionnaire data on sleep quality, physiological and psychological wellbeing	Quiet side improved sleep quality, physiological and psychological well being with 30-50% LAeq < 60 dB(A) at most exposed side is recommended

Appendix II: Laboratory studies

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
1	Aydin Y Kaltenbach M	Noise perception, heart rate and blood pressure in relation to aircraft noise in the vicinity of the Frankfurt airport.	2007	53 50-52 (+/- 15)	Air LAeq 50 dB outside (take off areas compared to non take off areas)	BP and HR monitoring and subjective measures	BP higher in higher exposed group 50 dB(A) limit (3/4 of time) in control group a relation was found with subjective measures but not in the highly exposed group.
2	Basner M	Nocturnal aircraft noise exposure increases objectively assessed daytime sleepiness	2008	24(12 male/12 female) age range 24-45	Air varying degrees of aircraft noise and quiet condition 9 nights noise events, LAeq	Pupillary unrest after as indicator for objective sleepiness	Increase of response to events and equivalent noise levels not exceeding pathological levels First study relating objective measure to aircraft noise
3	Basner M Glatz C Griefahn B Penzel T Samel A	Aircraft noise: effects on macro- and microstructure of sleep	2008	10	Air L_{MAX} 45 65 dB(A)	Macro and micro structures	Effect on sleep parametrers is differential, Awakenings and sleep stage and EEG arousals are recommended as robust measures
4	Basner M Muller U Elmenhorst EM Kluge G Griefahn B	Aircraft noise effects on sleep: a systematic comparison of EEG awakenings and automatically detected cardiac activations	2008	112 male females 24-50	Air, L_{MAX}	Cardiac reaction	An association was found between noise exposure (L_{MAX}) levels and cardiac reactions. If spontaneous awakenings were accounted for the curve is comparable to EEG

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
5	Basner M Samel A.	Nocturnal aircraft noise effects.	2004	Na	Air	na	Rationale for DLR study (too few studies, methodological differences and lack of criteria for health protection)
6	Basner M Samel A	Effects of nocturnal aircraft noise on sleep structure	2005	128 16 controls	Air noise levels between 45 – 80 dB(A)	Polysomnography (sleep onset, latency, awakenings, sleep stage shifts	Shifts were confirmed, SWS reduced , increase of total sleep time, no effect on stage 2 and REM. Threshold levels of number events * levels are defined (4*80, 8*70 16*60 32 * 55 64*45)
7	Basner M Siebert U	Markov state transition models for the prediction of changes in sleep structure induced by aircraft noise	2007	68 living near Cologne Airport	Air max sound pressure levels 3 conditions: no noise, early, end of night	Markov processes: sleep an wake, duration, elapsed sleep time	NB secondary analysis on DLR data Simulation Increase in time spent awake highest for late condition (5,9 versus 3,8 minutes) more pronounced sleep structure effects in late condition. Suggestion of a malus of 1.4 dB in second half of night

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
8	Basner M Siebert U	Markov state transition models for the prediction of noise-induced sleep disturbances	2006	64	Air max sound pressure levels Three conditions: no noise, early, end of night	Markov processes: sleep an wake, duration, elapsed sleep time	NB secondary analysis on DLR data Simulation Increase in time spent awake highest for late condition (5,9 versus 3,8 minutes) more pronounced sleep structure effects in late condition. Suggestion of a malus of .,4 dB in second half of night
9	Basner M Isermann U Samel A	The application of the DLR-study for a medical evaluation of a protective concept on adverse effects of nocturnal aircraft noise	2005	See field study Basner et al.	Air Max sound pressure levels	Awakening, onset of sleep	Secondary analysis on field data of the DLR study Noise protection zones defined based on aircraft noise and sleep effects less than 1 additional awakening no recall of awakening no interference with sleep onset
10	Brink M Lercher P Eisenmann A Schierz Ch EXP/Field study	Influence of slope of rise and event order of aircraft noise events on high resolution actimetry parameters	2008	14 during 7-21 nights	Air /prerecorded noise events	Bodily reaction before awakening,measured by actimeter, cardiac and reps parameters	Motility reactions strongest to aircraft events early in morning. short intervals, slope . Findings in line with recent findings on awakenings from rail an air noise

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
11	Campbell K Michaud DS Keith SE Muller-Gass A Wiebe S	Event-related potential measures of the disruptive effects of trains of auditory stimuli during waking and sleeping states	2005	12	Rail Simulated 80 or 60 dB sound pressure levels during 2 nights	EEG and subjective sleep disturbance	EEG effects and changes might have a protective effect against obtrusive sounds
12	Carter N Henderson R Lal S Hart M Booth S Hunyor S	Cardiovascular and autonomic response to environmental noise during sleep in night shift workers	2002	9 females shiftworkers	Air (military) Lmax 55/65/75	Polysomnographs (awakenings and EEG) HR, BP	HR associated with level but not type of noise BP sudden onset (related to awakenings and EEG Indicative of increased sympathetic activity HR no noise effect No habituation BP variability shown to be a sensitive measure to be used in field studies
13	Graham JM Janssen SA Vos H Miedema HM	Habitual traffic noise at home reduces cardiac parasympathetic tone during sleep	2009	36	Road/Rail	Indices of cardiac sympathetic and parasympathetic nervous System tone	RSA related to noise exposure (neg) esp during stage2, Noise levels related to cardiac parasympathetic withdrawal, no effect on cardiac sympathetic tone
14	Griefahn B Brode P Marks A Basner M	Autonomic arousals related to traffic noise during sleep.	2008	24	Road Lmax 32/45-77 dB(A)	HR polysomnograph	Response regulated by awakenings and not by noise per se. No habituation to traffic noise Increased effect when awakenings occur

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
15	Griefahn B Spreng M	Disturbed sleep patterns and limitation of noise	2004	Na	Air, road, rail	na	Nighttime exposure to intermittent sound (irrespective of source) most disturbing
16	Griefahn B Jansen G Scheuch K Spreng M	Assessment values of effects of noise on human beings for new constructions or considerable changes of airports	2002	Change	Air	na	Synthesis in order to set threshold levels in change situation (expansion airport)
17	Griefahn B Marks A Robens S	Noise emitted from road, rail and air traffic and their effects on sleep	2006	32 men an women	Road, rail air LAeq/32/39/44/50 dB and Lmax of 50-62 and 62-74	Polysomnograph, sleep quality, performance, reaction time	Gradual decrease in subjective sleep qol and reaction time Physiological reactions at all levels No source effect but f\physiological reactions stronger for rail LAeq good metric for subjective effects but not for physiological effects
18	Hoeger R	Aircraft noise and times of day: Possibilities of redistributing and influencing noise exposure	2004	Na Overview of evidence re noctural exposure and sensitivity to noise	Air		Shift of nighttime flights to daytime recommended (time and spatial redistribution)
19	Ising M [German]	Nocturnal traffic noise and stress hormone elevations in children].	2002	No abstract	Road		

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
20	Kuroiwa M Xin P Suzuki S Sasazawa Y Kawada T Tamura Y J	Habituation of sleep to road traffic noise observed not by polygraphy but by perception	2002	9 male 19-21	Road Exposed non exposed (< and > 50 dB(A)	Sleep stages, REM, onset, maintenance of sleep, Sleep quality	Habituation on all quality measures no habituation on physiological effects
21	Marks A Griefahn B Basner M	Event-related awakenings caused by nocturnal transportation noise	2008	24 male female aged 19-28	Rail/road /air Laeq 40-76 dB(A)	Polysomnograhs	Increase of awakenings with max, slope, duration and intervals between events Gender ns and age no influence Lower during sws Largest difference between rail and air Second part of night more relevant
22	Marks A Griefahn B	Associations between noise sensitivity and sleep, subjectively evaluated sleep quality, annoyance, and performance after exposure to nocturnal traffic noise.	2007	24 male/female aged 19-28	Rail Laeq 32, 40, 44, 50 dB(A)	Polysomnograhs, awakening, sleep quality, performance	Physiological effects in all conditions, perceived disturbance > 40 Performance no association but associated with SWS (>32 dB(A) Physiological and subjective measures modified by NS
23	Maschke C Hecht K Wolf U	Nocturnal awakenings due to aircraft noise. Do wake-up reactions begin at sound level 60 dB(A)?.	2004	Na	Air (60 versus 48 limit value) L_{MAX}	awakenings	Recommends 45 limit for road and rail and 60 for air

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
24	Michaud DS Miller SM Ferrarotto C Konkle AT Keith SE Campbell KB	Waking levels of salivary biomarkers are altered following sleep in a lab with no further increase associated with simulated night-time noise exposure.	2006	12	Rail Simulated 5 x 500 minute simulated alarms	Saliva (cortisol , melatonin)	No saliva effects Only subjective effects after 2nd night in laboratory Sleep QOL better at home
25	Ohrstrom E	Sleep studies before and after - Results and comparison of different methods	2002		Road		
26	Ohrstrom E Skanberg A	Longitudinal surveys on effects of road traffic noise: substudy on sleep assessed by wrist actigraphs and sleep logs.	2004		Road		
27	Ohrstrom E Skanberg A	Sleep disturbances from road traffic and ventilation noise -laboratory and field experiments	2004	18	LAB AND FIELD Road and ventilation noise Measured n lab and home	Motility and sleep quality and mood	20% reduction of sleep quality in lab, combination of road and ventilation 25% reduction in awakening, movements and qol, measured by questionnaires none of these effects showed in motility No difference between field and lab results

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
28	Pirrera S De Valck E Cluydts R	Sleep and road traffic noise: day by day variability in actigraphic recordings and sleep diaries	2008		Road		
29	Quehl J Basner M	Annoyance from nocturnal aircraft noise exposure: Laboratory and field-specific dose-response curves.	2006	128	Air L_{MAX} /SEL LAeq 45-80 DB9A and nr of events 4-128	annoyance	In lab increase of annoyance related to SEL and Lmax, Increase with Lmax in nights with < 16 fly overs, Laeq also related but decrease since less fly overs. Dose response comparable in field data , but annoyance higher in lab setting. Combination of Laeq and number of events is recommended

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
30	Quehl J Basner M	Annoyance caused by nocturnal aircraft noise in laboratory studies	2005	128	Air Lmax/ SEL LAeq	annoyance	Annoyance (next day) related to Laeq, Lmax and SEL. Above 46,6, dB(A) decrease since nr of events reduces Unlike previous studies, the portion of aircraft noise annoyed persons also increases with L,max at few movements (<16 over-flights per night). gender, their pre-annoyance by aircraft noise and the rated necessity of air traffic are proved to be relevant moderator variables of aircraft noise annoyance.
31	Riethmuller S Muller-Wenk R Knoblauch A. Schoch OD	Monetary value of undisturbed sleep.	2008	Na	Na	Monetary value of undisturbed sleep	Undisturbed sleep by noise: high monetary value compared to other causes
32	Samel A Basner M	Extrinsic sleep disorders and effects of noise	2007 no abstract	Na evaluation			Noise studies are evaluated, small study groups, differences in statistical analysis and lack of control group as major problems . Interdisciplinary collaboration is recommended
33	Samel A Basner M Isermann U	Aircraft noise effects on sleep: DLR research results and their application	2007				

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
34	Samel A Basner M Maass H Mueller U Quehl J Wenzel J	" Effects of nocturnal aircraft noise on sleep: Results from the "Quiet Air Traffic" project	2005	192, 112 lab, 64 field, 16 controls 9 nights	Air, varying aircraft noise levels expressed in Max aircraft noise events (check	Sleep indicators, stress (hormones) performance subjective factors	In Lab EEG effects (awakening) In the field awakenings above 33 dB(A) In lab., cortisol effects, reduction of sleeping time no performance effects Lab more pronounced
35	Saremi M Greneche J Bonnefond A Rohmer O Eschenlauer A Tassi P	Effects of nocturnal railway noise on sleep fragmentation in young and middle-aged subjects as a function of type of train and sound level.	2008	20 mostly women -26 years	Rail LAeq 35/40/50	EEG Arousal	Lowest effect in REM, highest effect in stage 2 Awakenings related to type of train (freight) Microscopic indicators of sleep fragmentation are considered to be relevant and useful in future sleep studies
36	Sasazawa Y Kawada T Kiryu Y Suzuki S	The relationship between traffic noise and insomnia among adult Japanese women	2004	59 women EPI	Road, Distance 20-50, 50-200 > 200 Laeq 52, 57, 65	Insomnia	No difference in prevalence of Insomnia Actual traffic should be measured
37	Schapkin SA Falkenstein M Marks A Griefahn B	After effects of noise-induced sleep disturbances on inhibitory functions	2006	22	Rail LAeq 39/44/50	Performance and brain activity (EEG)	Effects found on EEG but not subjective qol or performance Task difficulty and perceived sleep quality were important moderators Exposure might be related to physiological costs even if level of performance maintained

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
38	Schapkin SA Falkenstein M Marks A Griefahn B	Executive brain functions after exposure to nocturnal traffic noise: effects of task difficulty and sleep quality.	2006	20	Road LAeq 39, 44, and 50 dB(A)	Performance EEG and subjective measures	Sleep quality in bad sleepers worsened steadily with increasing noise levels. No effects of noise or subjective sleep quality on performance were found. Inhibitory processes appear to be selectively impaired after nocturnal noise exposure. The task difficulty and perceived sleep quality were important factors modulating noise effects.
39	Scheuch K	Special assessment of aircraft noise effects during night by the Council of Environmental Questions of FRG Experts for	2004	EVAL	Air		
40	Skanberg A	Road traffic noise-induced sleep disturbances: a comparison between laboratory and field settings	2004	18`	Road	Motility and subjective measures	Comparison shows that the effect at home and in laboratory is comparable, no exaggeration in lab situation
41	Spreng M	Health consequences of aircraft noise: Noise research is hampered	2009	Na	Air		Commentary paper/abstract not available

#	Author	Title	Year	Subjects	Exposure Measurement	Outcome	Results
42	Toelke R [German]	Noise level measurements in sleeping rooms during night time in sites with aircraft noise annoyance and test of passive noise abatement measures /	2003	Not mentioned	Air Lmax (55dB(A) single night In bedroom and outdoors	Na	Limit of maximum of 55 dB(A) was confirmed
43	Kaltenbach M Maschke C Klinke R	Gesundheitliche Auswirkungen von Fluglärm	2009	NA(discussion paper)	Air		

Appendix III: Field studies (not peer reviewed)

Author	**Title**	**Year**	**Subjects**	**Exposure source and Measurement**	**Outcome**	**Results**
Passchier-Vermeer W Miedema HME Vos H Steenbekkers HMJ Houthuijs D Reijneveld SA	Sleep disturbance and aircraft noise exposure (in Dutch).	2002	419	Air living at various levels around Schiphol Airport	Actimetry Diary Questionnaire	Increase in motility at lower levels than expected Long term exposure to relative low levels associated with higher sensitivity to noise events than at higher levels Sleep onset, awakenings medication use and motility associated with equivalent noise levels indoor during sleep No effect on reaction time Night time annoyance and number of health complaints associated to long term exposure Exposure effect relationships were used to estimate the prevalence of sleep effects
Passchier-Vermeer W Vos H Janssen SA Miedema HME	Sleep and traffic noise	2007	262	Road L_{MAX} 45dB(A)	Actimetry 36 subjects ECG	
Passchier-Vermeer W	Night-time noise events and awakening.	2003		Road Field lab		
Basner et al	Effects of nocturnal aircraft noise	2004	192 128 lab 64 field age range 18-52	Air		

Appendix IV: Available dose response relationships (source: Van Kempen et al., 2005)

Study (year)	Outcome		Derived curve	
	Definition	Measurement	Formula [a)]	Remarks
Lukas 1975	Average % of behavioural awakenings	Behavioural (button)	% persons without sleep disturbance = -1.552 * L + a	
Lukas 1975	Average % of sleep stage changes	EEG patterns		
Griefahn 1976	Awakening		Probability awake = 1.32 * L_{Amax} – 79.67	Source: Hoffman '94
Griefahn 1976	Sleep stage changes			
Pearsons et al., 1989	Percentage of awakenings		% Aroused = 0.1159*L_{Amax} – 4.7249	Sound levels in bedroom, derived from field studies
Pearsons et al., 1989	Percentage of sleep stage changes		% Sleep disrupted = 0.7748*L_{Amax} – 22.0715	Sound levels in bedroom, derived from field studies
Finegold, 1994	Awakenings		% Awakenings = 7.1 x 10^{-6} * $L_{AE}^{3.5}$	Indoor sound levels
Hoffman 1994	Probability awake _ air	EEG patterns	Probability awake = 0.43462 * L_{Amax} – 9.1415	
Hoffman 1994	Probability awake_road	EEG patterns	Probability awake = 1.0357 * L_{Amax} – 42.749	
Fidell 1998	Percentage of subjects awake	EEG patterns, behavioural, actimetry		
Finegold and Elias 2002	Percent of awakenings	EEG patterns, behavioural, actimetry	% awakenings = 0.58 + (4.30 x 10^{-8}) x SEL $^{4.11}$	
Passchier 2003	Percentage noise induced awakenings	EEG patterns, behavioural, actimetry	% noise-induced awakenings = -0.564 + 1.909x10^{-4} x SEL_i^2	Indoor, in bedroom
Passchier et al, 2002	Noise-induced mean motility	Actimetry	Noise-induced mean motility = 0.000192 x (L_{night} – 21)	The difference between L_{night} and the similar L_{Aeq} at the façade of the bedroom is assumed 0 dB(A); The difference between the night-time L_{Aeq} outdoors at the façade of the bedroom and in the bedroom during the sleep period is assumed to be 21 dB(A)
Passchier et al., 2002	Probability of motility	Actimetry	Max expected number of intervals with motility = N x [0.0001233 x (L_{night} + 70.2 – 10 lgN – 21)^2 – 0.007415 x (L_{night} + 70.2 – 10 lgN – 21) + 0.0994]	The difference between L_{night} and the similar L_{Aeq} at the façade of the bedroom is assumed 0 dB(A); The difference between the night-time L_{Aeq} outdoors at the façade of the bedroom and in the bedroom during the sleep period is assumed to be 21 dB(A)

Miedema et al., 2003	Percentage highly sleep disturbed, sleep disturbed and a little sleep disturbed	Questions regarding waking up or being disturbed by noise during night	$\%HSD = 20.8 - 1.05 * L_{night} + 0.01486 * L_{night}^2$ $\%SD = 13.8 - 0.85 * L_{night} + 0.01670 * L_{night}^2$ $\%LSD = -8.4 + 0.16 * L_{night} + 0.01081 * L_{night}^2$
Miedema et al., 2003	Percentage highly sleep disturbed, sleep disturbed and a little sleep disturbed	Questions regarding waking up or being disturbed by noise during night	$\%HSD = 11.3 - 0.55 * L_{night} + 0.00759 * L_{night}^2$ $\%SD = 12.5 - 0.66 * L_{night} + 0.01121 * L_{night}^2$ $\%LSD = 4.7 - 0.31 * L_{night} + 0.01125 * L_{night}^2$
Miedema et al., 2004	Percentage highly sleep disturbed, sleep disturbed and a little sleep disturbed	Questions regarding waking up or being disturbed by noise during night	$\%HSD = 18.147 - 0.956 * L_{night} + 0.01482 * L_{night}^2$ $\%SD = 13.714 - 0.807 * L_{night} + 0.01555 * L_{night}^2$ $\%LSD = 4.465 - 0.411 * L_{night} + 0.01395 * L_{night}^2$
Breugelmans et al. 2005	Percentage highly sleep disturbed	Question regarding being disturbed by noise during night (past year; 11 pointscale)	$Logit(\%HSD) = -6.642 + 0.1046 * L_{night}$ %HSD=(exp(logit(%HSD)/(1+(exp(logit(%HSD))))*100 ++)

a) % HSD = Percentage highly sleep disturbed; % SD = Percentage sleep disturbed; %LSD = percentage (at least) a little sleep disturbed. ++) The derived exposure-response relationship is based on modelled flight paths

Appendix V: Background papers for the EU policy papers

V. I Scientific background papers for the EC position paper on nighttime noise

TNO/Miedema et al, 2004

As input for the EC position paper TNO prepared an overview of available dose-response relationships in 2003. Based on the evidence at that time, two dose response relations are presented: motility and self reported sleep disturbance. The paper gives an overview of the studies performed on the different sleep indicators, mostly referring to studies from before 2002 with the exception of the airport sleep study by Passchier (2002). It is concluded that SEL and Lmax were found to be related to instantaneous (onset of) motility (measured by actimetry and EEG), and behavioural awakening, (button push). . Sleep latency time (or sleep onset latency: SOL) and mean motility as measured by polysomnography and actimetry respectively showed to be associated with LAeq, while mean motility has been associated with L_{night}. Of these measures, only sleep latency and motility (over a night and mean motility over longer periods) are positively associated with indicators of subjective sleep quality and/or perceived awakenings, health complaints and adverse sleep effects. The paper further described the meta analysis Miedema performed on a pooled data set regarding sleep disturbance, which are further discussed in paragraph 1.3 and 3.4.

Health Council of the Netherlands

Also within the framework of EU policies regarding night time noise, the Health Council of the Netherlands (HCN) prepared a report on noise and sleep in 2004 on request of the Secretary for Housing, Spatial Planning and the Environment as an update of their 1994 review. In this review, the HCN Committee distinguished five categories of effects:

• Reduced sleep quality
• Reduced general well-being
• Impaired social interaction and reduced concentration during day-time
• Specific disease symptoms
• Loss of years of life (premature mortality).

The available evidence was rated as sufficient, limited, or insufficient.

The conclusions of this review were that:

- There is sufficient evidence that night-time noise events cause direct biological responses, such as increased heart rate, reduced depth of sleep, increased motility and awakening at levels above a *SEL* of 40 dB(A) or L_{MAX} of 32 dB(A).. Behavioural awakening (established by pressing a button) occurs when the bedroom *SEL* exceeds 55 dB(A).
- There is sufficient evidence of a relationship between exposure to night-time noise and average motility, which in its turn is associated with more frequent awakening, lower perceived sleep quality and increased daytime drowsiness.
- There is sufficient evidence that people, who are exposed to environmental noise during sleep or are concerned about being disturbed by noise in the night, have more difficulty falling asleep (increased sleep onset latency). There is sufficient evidence that nighttime noise exposure is associated with a reduction in general well-being evident from self-reported sleep disturbance, self reported health problems, use of sleeping pills and sedatives, and adversely affected daytime mood

- Where insomnia is concerned the evidence of a causal relationship was considered as sufficient, but only limited evidence of an increased risk for other diseases such as depression, diabetis and CVD (*CHECK)and also limited *indirect* evidence of an increased risk of involvement in a fatal accident at work as a result of sleeping problems and insomnia associated with exposure to night-time noise.
- There is limited evidence that under certain circumstances night-time noise can influence stress hormone levels in particular in women.
- There is limited evidence that exposure to night-time noise has a negative impact on social interaction, on the performance of concentration-sensitive tasks during the day, on specific complaints or disease symptoms and on loss of life years due to fatal accidents at work.
- Riskgroups identified were: older people, pregnant women, women who have given birth within the preceding 12 months or so, people who regularly work at night, people with sleep disorders, physical pain, dementia, depression, hypertension, heart disease and pulmonary disease.
- Based on the available information on prevalence of exposure, the number of people affected and the DALYS were estimated for the Netherlands population. The following knowledge gaps were identified: long-term effects of night-time noise on health and well-being, the effects of night-time noise on children, the effectiveness and efficiency of noise attenuation measures for façades and between dwellings, and the effects of noise produced by neighbours or by one's general neighbourhood.
- L_{DEN} and L_{NIGHT} were proposed as suitable noise metrics, providing a considerable degree of protection against noise during sleep. However, for some effects this is not sufficient, the single event level and maximum level (SEL, L_{MAX}) should also be taken into account, bearing in mind that the effectiveness of a limitation measure based on events can only roughly be estimated with the current knowledge.

RIVM/Van Kempen et al

The review of van Kempen et al, in 2005 had a broader focus and was written against the background of health impact assessment of noise. The review addressed annoyance, sleep and cardiovascular diseases as endpoints. Most of the evidence described runs parallel with the HCN report above. The prime focus was on deriving dose response relationships. The overview of available dose response relations is presented in Appendix II and further discussed under paragraph 3.4.

V. II: Scientific background papers for the WHO NNGL

In preparation of the NNGs, several working groups were formed to prepare background documents which were externally reviewed. The major conclusions from these papers are summarised below, organised by individual effects.

The review on **acute effects** is partly based on studies from before 2002 and partly on some major studies since then. It is concluded that sleep is well protected (in terms of awakenings) but that the physiological reactions do not adapt, as shown by the heart rate reaction and the increase of average motility with sound level. The autonomous physiological reactions are a normal reaction to these stimuli, but it is not clear is from current evidence what the long term adverse consequences are for the organism.

After effects of sleep disturbance background papers were prepared on cognitive effects, mental health effects and subjective sleep quality.

Regarding **cognitive after effects** of sleep deprivation, Hygge deduced that noise in the early night, e.g. aircraft noise before midnight, could be particularly damaging to memory and related cognitive functions, but this implication has not yet been explicitly tested. New evidence points in the direction of an increased effect on memory due to noise in the early night, but there is as yet no graded quantification about whether ordinary before-midnight noise levels around large airports are sufficient to make a difference to slow wave sleep (SWS) .Further, since children's memory systems pass through developmental changes and are not structured in the same way as for adults, it would be interesting to know to what extent the results are also valid for children, and whether the depth of children's sleep counteract or enhance the SWS dominance in the early night. An important conclusion is that studies into the cognitive effects of daytime noise levels cannot be used as a proxy for effects of night time exposure. Effects on motivation and further studies into the restorative function of sleep (Hartig, 2004) are mentioned as important topics for future studies

Important finding on the relation between (noise-related) insomnia and **mental health**, reported by the background paper of Stansfeld, is that insomnia more often precedes rather than follows incident cases of a mood disorders (Ohayon, Roth 2003). Compared to good sleepers, severe insomniacs reported more medical problems, had more physician-office visits, were hospitalized twice as often, and used more medication. Severe insomniacs had a higher rate of absenteeism, missing work twice as often as did good sleepers. They also had more problems at work (including decreased concentration, difficulty performing duties, and more work-related accidents) (Leger et al, 2002). It is concluded that evidence regarding the role of noise exposure, sleep and the development of depression, is still scarce. Three criteria have been suggested for sleep disturbance to be environmentally determined: (1) the sleep problem is temporally associated with the introduction of a physically measurable stimulus or definable set of environmental circumstances; (2) the physical rather than the psychological properties of the environmental factors are the critical causative elements; and (3) removal of the responsible factors results in an immediate or gradual return to normal sleep and wakefulness (Kraenz et al, 2004). Most studies do not fulfil these criteria.

In a third paper the **disability weight**[4] of chronic sleep disturbance was estimated by Muller-Wenk based on interviews with medical professionals and it was found that irrespective of

[4] disability weight: The disability weight lies on a scale between 0 (indicating the health condition is equivalent to full health) and 1 (indicating the health condition is equivalent to death).

the question whether self-reported sleep disturbance is formally recognised as a disease or not, its severity is comparable to commonly accepted diseases. A mean disability weight for self-reported sleep disturbance due to road traffic noise was found to be 0.055 (CI 0.039; 0.071) which is roughly in line with weights for severe sleep disturbance as reported in e.g. Knol and Staatsen, 2005, and Schram et al, 2009). Based on these two findings an average weight of .07 was proposed.

It is concluded that only a few epidemiological studies exist on the cardiovascular effects of **long-term** noise exposure in the bedroom during the night. An exception is a study of Maschke et al, 2003b), the results of which suggested slightly higher effect estimates (odds ration 1.9 vs. 1.5), for the prevalence of hypertension with respect to the noise exposure of the bedroom (during the night) compared with the exposure of the living room (during the day). Critique on these findings is directed at the composition of the sample (older and health conscious group) There is some new evidence that the association between annoyance and CVD outcomes is stronger for sleep related annoyance/disturbance (Babisch et al, 2005; Maschke et al, 2003a; Niemann and Maschke, 2004). Sleeping behaviour such as closing windows, changing rooms etc are assumed to play a role in this association.

Separately, there have been several papers on noise and sleep prepared as background for a forthcoming WHO Practical Guidance for Risk Assessment of Environmental Noise on Health. The review on noise and sleep (Basner and Griefahn, 2008) briefly summarises the evidence of noise induced sleep disturbance and its different indicators. In contrast to Berry and Flindell (see below) they conclude that clear exposure-response relationships have been demonstrated between single noise events and arousals, awakenings or body movements (see e.g. Basner et al, 2006; Finegold et al, 2002; Marks et al; 2008; Passchier, 2002, 2003, 2007) Exposure-response relationships between L_{NIGHT} or similar integrated measures and sleep disturbances are rare (Quehl, 2008, Passchier et al, 2007), which may in part be attributed to the fact that L_{NIGHT} is a whole night indicator and thus can only be related to whole night sleep parameters. As worded by the authors: *In the WHO's Night Noise Guidelines (2009) , several L_{NIGHT} exposure categories are linked to health and sleep disturbance outcomes, and can accordingly be used to assess the degree of sleep disturbance. Additionally, it is possible to use exposure-response relationships between L_{NIGHT} and sleep disturbance indicators (like additionally induced awakenings) to directly assess the expected degree of sleep fragmentation. However, nocturnal sleep disturbance primarily depends on the number and acoustical properties of single noise **events**, and it may therefore be advantageous to directly use these predictors instead. The END explicitly states that it may be advantageous to use maximum SPL L_{Amax} or sound exposure levels (SEL) as supplementary noise indicators for night period protection. [note: this discussion is one of the key issues that comes forward in the recent papers on the relationship between noise and sleep disturbance]*

Backgrounds for monetization of effects due to of environmental noise (UK GOV)

Recently, Berry and Flindell (2009) published their technical report *Estimating Dose-Response Relationships between Noise Exposure and Human Health Impacts in the UK,* which gives again a broad overview of the health impacts of noise, including sleep. The study is aimed at providing the information needed for monetization/valuation of noise related health effects, an endeavour which is being prepared by the national UK Government's Interdepartmental Group on Costs and Benefits of Noise subject group. They have based their sleep review on the same documents as described above and consequently there is a great deal of overlap. Noteworthy is their conclusion regarding the available exposure-response relationships that, at present, no reliable exposure-response relationship for noise and sleep disturbance-related health effects exists, which is useful for monetary valuation of adverse health effects. They consider exposure-response curves for self-reported sleep disturbance (included in the EU Position paper of 2004) as the most "reputable" and best available at the moment. As worded by the authors: *The reviews have shown that there appears to be no single noise exposure metric or general measurement approach that is generally agreed upon for noise-induced sleep disturbance and ……Transient disturbances should not be considered to be significant adverse health effects on their own unless they also lead onto, or can be shown to lead onto, some more significant chronic or persistent adverse health effect as an intermediate step in a causal chain. In this area, transient disturbances or physiological indicators are of less interest than persistent changes in metabolism or alertness.*

Reflective papers

In his background paper for the WHO updated night time noise guidelines, Muzet (2003) summarised 30 year evidence regarding the relation between noise and sleep and focused on the fact that large discrepancies were found. The review addresses the question whether this is the result of the complexity of noise exposure and its effect on peoples sleep, or whether related to basic methodological differences. The review is to a large extent based on the literature before 2002 and for a summary of findings up till then we refer again to previous overviews. However its new insights were primarily related to the role of non acoustical factors, such as home, individual characteristics, and social determinants. Muzet stresses the need for studies which address the relationship between objective and subjective sleep disturbance. If it is true that objective and subjective measures are weakly correlated, their effects should be considered separately. Another discrepancy the review touches on is that between laboratory and field findings, warranting a combination of both approaches in one study or applying laboratory techniques to real life situations. The published review of Muzet in 2007 is an update of this earlier one including literature from some more recent studies. The issue of low correlations between objective and subjective measures is further discussed and reference is made to Passchier (2003) who, in her airport sleep study, showed that subjective self-reports on sleep quality or on nocturnal awakenings do not correlate well with more objective measures of sleep disturbance.