Emission, dispersion and health effects of air pollutants and community noise in Scania - an integrated study on road-, railway-, air- and sea traffic and industries

Introduction

The health effects of air pollution are important in a population perspective, and even at exposure levels in Sweden, that in an international comparison are at the low range, the effects may be considerable in a public health perspective. It has been estimated that pollution shortens the expected life length in Scania by as much as 7-10 months [Forsberg et al, 2005]. Childhood exposure and effects on lung function development and respiratory disease are well known [WHO 2003, Gauderman et al 2007] In adults, there is now evidence for long-term exposure effects on COPD and asthma [WHO 2003, Sunyer et al 2006], but effects on rhinitis and eczema are unclear. Evidence has been presented that air pollution has trigger (short-term) effects on the risk of stroke [WHO 2003] and effects of long-term traffic exposure have been indicated for stroke [Maheswaran net al 2003, Miller et al 2007]. The situation is similar for cardiac disease.

Traffic is the main local source of air pollutants, and of community noise. Thus, both air pollution and noise may be important risk factors for cardiovascular disease. Traffic noise is annoying and air traffic noise is a risk factor for hypertension, whereas there is less evidence for road traffic noise [Babish 2006].

There is also mounting evidence that air pollution can affect reproductive outcome, i.e. respiratory deaths in the postnatal period, birth weight, intrauterine growth retardation and preterm births [Srám et al 2005], but well-designed studies taking individual confounders into accounts are clearly needed.

Neither effects of concomittant exposures to air pollution and noise are hitherto sufficiently elucidated, nor is socioeconomic and sociodemographic confounding and/or effect modification effect. Especially in densely populated areas, the infrastructure for traffic is an important component of the physical environment. Negative aspects of built environments have been linked to physical inactivity and obesity.[Ewing et al 2003, Papas et al 2007]. Less emphasis has been put on the tentatively protective role of close access to natural environments, and few large population-based studies have been based on objective assessments [deVries et al 2003, Maas et al 2006]. A better understanding of the complex interplay between individual and contextual determinants of health is clearly needed.

Adequate exposure assessment is a key factor in environmental epidemiology. Geographic information systems (GIS) are being used with increasing frequency, especially for exposure assessment, and have enhanced the understanding of the association between contaminants in our environment and disease [Nuchols et al 2004]. For large-scale population studies, modelling of exposure is a prerequisite [Gilliland et al 2005]. GIS is a valuable tool for description and analysis of all determinants for health and disease that can be localized in time and space, including the interplay between individual and contextual life-style factors in the

human environment. Thus, GIS can be used in analytical epidemiology, as well as for surveillance of exposure and surveillance of health events**.**

Objectives

The *basic purpose* of this research program is to study associations between the environment in a broad sense and human health, thus identifying primary preventive measures. The use of geographical information systems (GIS) is the common methodological denominator for the research program.

We focus on environmental risk factors and health protective factors for multifactorial disorders of major concern for public health, in adults as well as in children. Access to a wealth of detailed exposure and outcome data on individual level for the Scanian population is unique in an international perspective. We will contribute to better understanding of the relative importance of traffic generated air pollution and noise in Scania for health and well-being, better knowledge about dose-response relationships, identification of susceptible population strata, and of health promoting factors in the physical human environment. Thus, the scientific basis for primary preventive actions will be strengthened.

The specific goals within the EMFO project were

1. to investigate the exposure levels to traffic generated air pollution and noise from different sources in the Scanian population, and to describe the covariation between these emissions, and sociodemographic conditions. During the project period we have also included health promoting aspects in the natural environment near the residence.
2. to investigate the effects of traffic generated air pollution and traffic generated community noise on respiratory and cardiovascular health and wellbeing, in the Scanian population. During the project period, studies on reproductive effects have also been added.
3. to review existing studies on the cost-of-illness (COI) of air pollution, and perform such a study

Part 1. Air pollution, noise, and natural environments in Scania

Environmental exposure assessment must rely on modelling in order to provide estimates for the entire population. Access to such modelled outdoor exposure data in Scania, as indeed for other large regions world-wide, is limited at present. With the current project, three important environmental databases have been assembled. We expect that several future studies of the population in Scania will use exposure data not only from one but from all three databases concurrently.

By linkage of residential geocodes to modelled levels of pollutants, exposure levels in the population (i.e. individual level data) can be assessed. In the present EMFO project we have had access to the geocode at the residential address for the population in the former county of Malmöhus for each year since 1983, and for the total Scanian population since 1998.

Database A - Exposure to air pollution:

Summary description

An emission database (EDB) is a collective concept for the amount and storage of emission data of air pollutions. The purpose of an EDB is to create a model for emissions in time and

space. The general structure of the EDB is often built up with four basic sources types. These four sources are stored digitally as: point, line, grid and area sources and then combined with information regarding spatial location, time of emission, physical factors (e.g. smoke speed in a chimney), emission explaining variables (e.g. number of vehicle and roads), emitted chemical pollutants, etc. The emission database used to obtain the exposure estimates in this project contains emission sources for nitrogen oxide (NOx), particular matter (PM10), carbon dioxide, sulphur dioxide and volatile organic compounds (VOC) in the Danish-Swedish region "Öresund" where the county Scania (Skåne) is included. The emission sources were collected with the base-year 2001 but due to recalculations and updates the database is valid for modelling of concentrations of NOx during the time period 1998 – 2006.

The software tool used for the EDB is ENVIMAN from OPSIS AB (OPSIS 2008). The digital map data used is the digital version of the "Öresundskartan" obtained from national survey and cadastre in Denmark. The map is equal to the Swedish map of the area, except that the Danish version includes Zealand (DK) as well as Scania (SE) and some part of the neighbouring counties Blekinge (SE), Halland (SE), Småland (SE) and the Baltic Sea. The emissions sources are grouped into the following categorises: Road traffic, Shipping, Aviation, Railroad, Industries and larger energy and heat producer, Small scale heating, Working machines, working vehicles and working tools, Emissions from neighbouring counties and Zealand. The information about emission sources and amount of emitted pollutants etc. was obtained from official sources such as the Swedish Road Administration, the Swedish Environmental Protection Agency, the Swedish maritime administration, the Swedish Civil Aviation Administration, etc.

In addition to the emission database a dispersion model is needed to model the distribution and concentration of air pollutants in an area. The software (Enviman) uses a Gaussian model for this (AERMOD) which, in combination with the EDB, allow high resolution modelling in space (effective resolution 10x10m) of air pollutions in Scania. The temporal resolution allows levels to be modelled with a resolution of one hour for the time period 1999 to 2005.

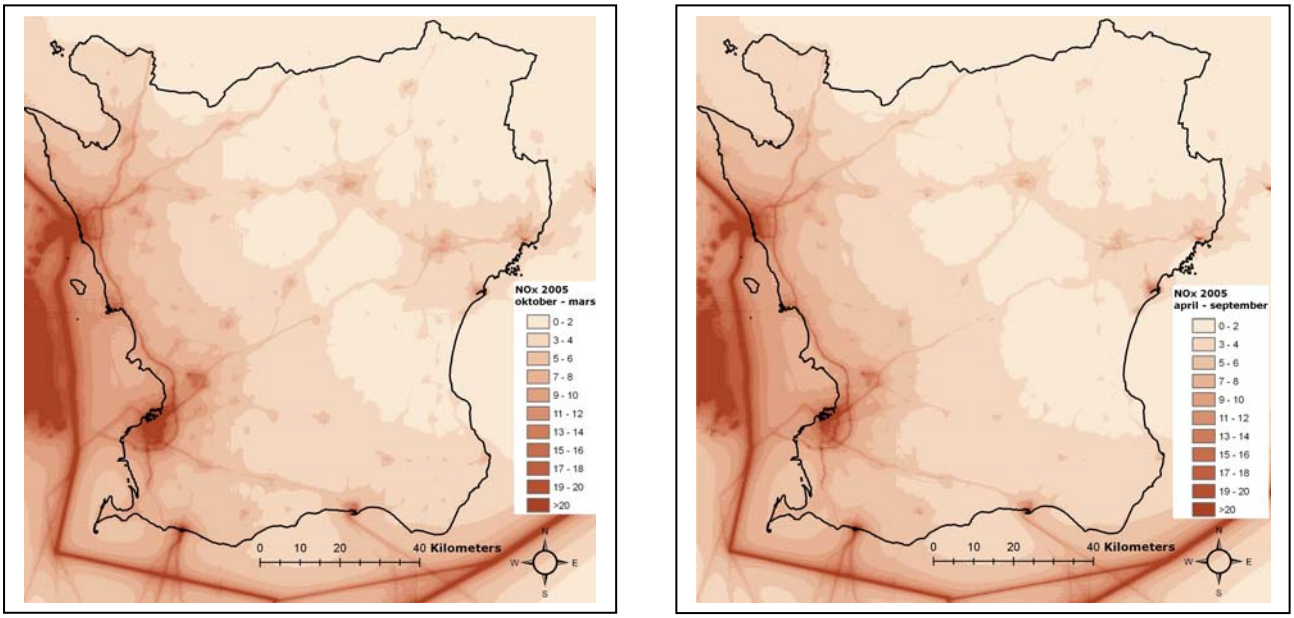

Figure 1. The spatial distribution of modelled NOx in the cold (Oct-March) and the warm (April-Sept) season in 2005. The resolution is 250 x250 m.

The modelled exposure levels in the population can be assessed by linkage of a geocoded population to geocoded modelled levels of pollutants. When modelled with a resolution of 250 x250 m, around 12% of the population have mean annual NOx levels exceeding 20 µg/m^3, and only a few individuals exceed an annual average of 40 µg/m^3 (Figure 2). When modelling with higher resolution, especially with street canyon models, assigned levels can be higher.

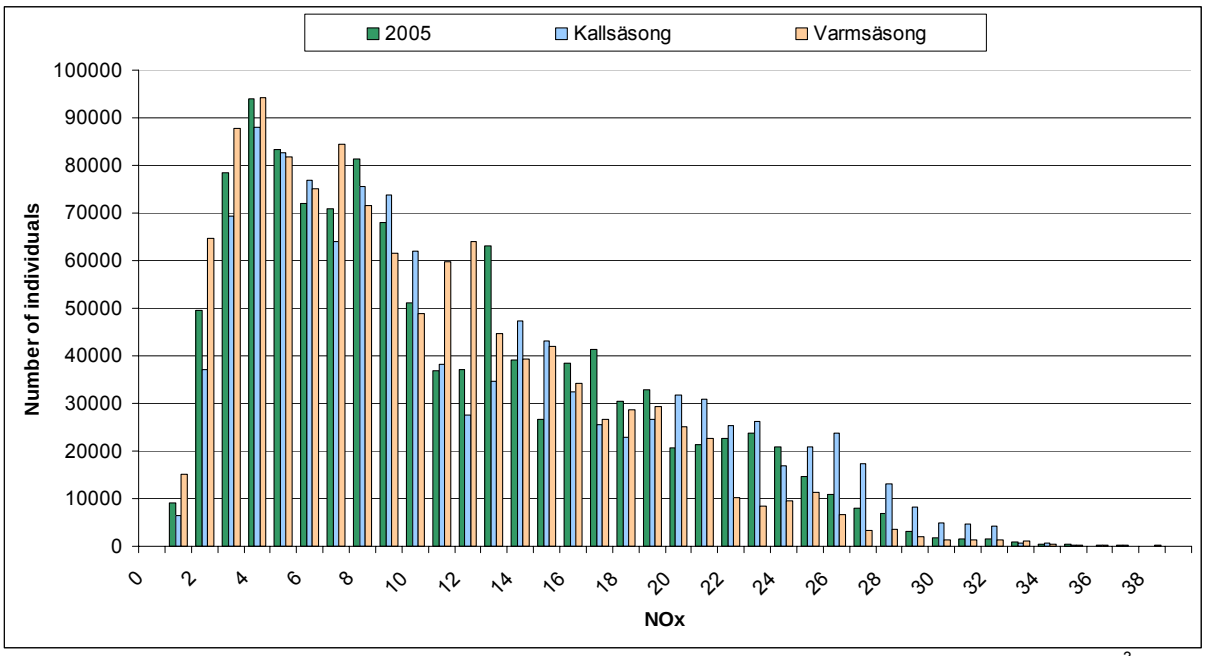

Figure 2. Mean annual (green bars), Nov-March (blue bars) and April-Oct (orange bars) NOx levels (µg/m^3) in the Scanian population in 2005. 12% of the population have modelled exposure levels exceeding 20 µg/m^3

The relationships between exposure to air pollution and socioeconomic characteristics in the population have been explored [Chaix et al 2005, Stroh et al, 2005]. Clearly, associations between socioeconomic characteristics and exposure to air pollution were not consistent between cities (Figure 3), and not always consistent between different indices of socioeconomic status.

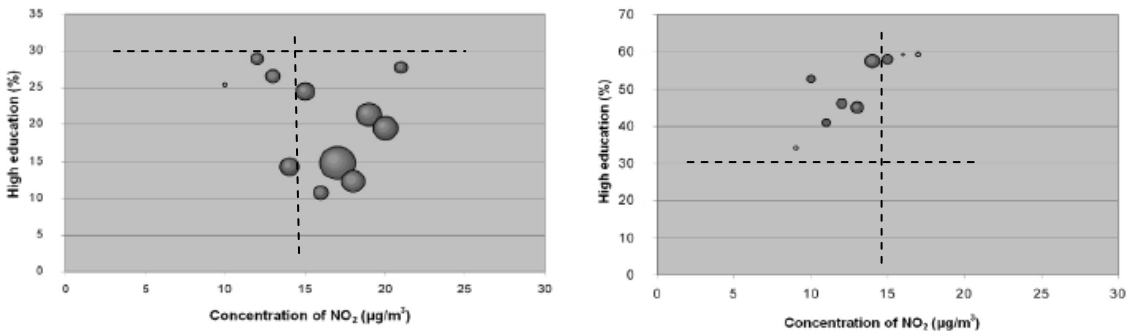

Figure 3. Percentage of population with high education versus annual mean concentration of NO2 at their residency. The bubbles are sized according to the weight of the estimate, which depends on the size of the population. From Stroh et al, 2005.

Validation

The EDB and modelling of exposures has been thoroughly validated against measured levels from monitoring stations, stationary residential sampling, and personal monitoring

(summarized in Gustafsson S, Licentiate thesis, 2007). An example of the performance is given in Fig 4.

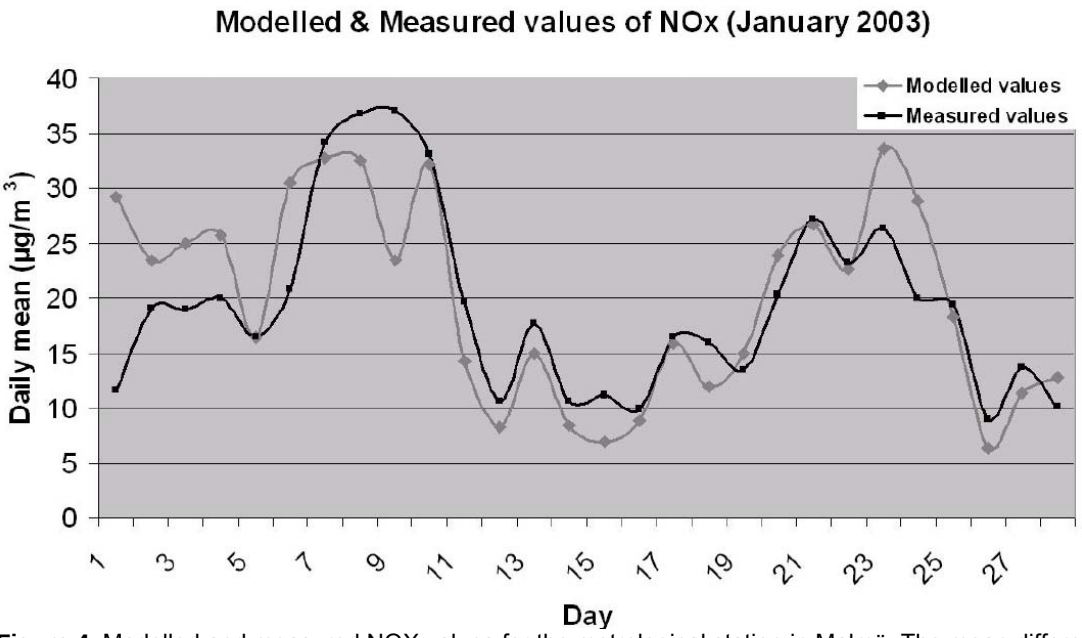

Figure 4. Modelled and measured NOX values for the metrological station in Malmö. The mean difference between the modelled and the measured value of NOx is 0.6*g/m3 and the standard deviation of the differences is 12.3 µg/m3 for the hourly difference, 5.9 µg/m3 for the daily difference and 4.4 µg/m3 for the weekly difference. From Stroh et al, 2007

Within the EMFO project further validation has been carried out (Friman et al, manuscript). 100 subjects, selected as to represent modelled levels of < 7µg/m^3, 8-11 µg/m^3 and > 12 µg/m^3 annual average NO2 participated in personal monitoring of NO2 during a week in autumn 2005, The samplings were repeated in spring 2006. 50 subjects also performed 1 week measurements of PM2.5 outside their home. Detailed diaries were kept. [Art 144]. Measured concentrations (Table 1) are compared with results from a dynamic modelling, taking home and workplace location and commuting patterns into account.

Table 1. Measured levels of NO_2 and $PM_{2.5}$ during 1 week personal and stationary samplings.

	Personal sampling		**Stationary sampling**	
	Autumn 2005	Spring 2006	Autumn 2005	Spring 2006
NO_2				
Number of subjects	86	64	88	66
Median [µg/m^3]	13	11	11	10
Range [µg/m^3]	5 - 32	4 - 29	5 - 46	4 - 26
25-percentile [µg/m^3]	10	8	8	8
75-percentile [µg/m^3]	16	15	15	14
$PM_{2.5}$				
Number of subjects	46	34	44	33
Median [µg/m^3]	7	9	5	6
Range [µg/m^3]	2 - 110	4 - 200	1 - 56	Nd - 36
25-percentile [µg/m^3]	5	6	3	5
75-percentile [µg/m^3]	17	15	11	11

We have evaluated the effects of varying resolution in time and space (Stroh et al, 2007). Concentrations modelled in urban areas with coarser resolution than 400 metres seem to

generate larger error estimates in areas with high contrasts. However, for rural areas, where the variations in air pollutants are much lower, even a grid size of 1600 metres seems to generate reasonable results. An example of the effects of varying spatial resolution in an urban setting is given in Fig 5.

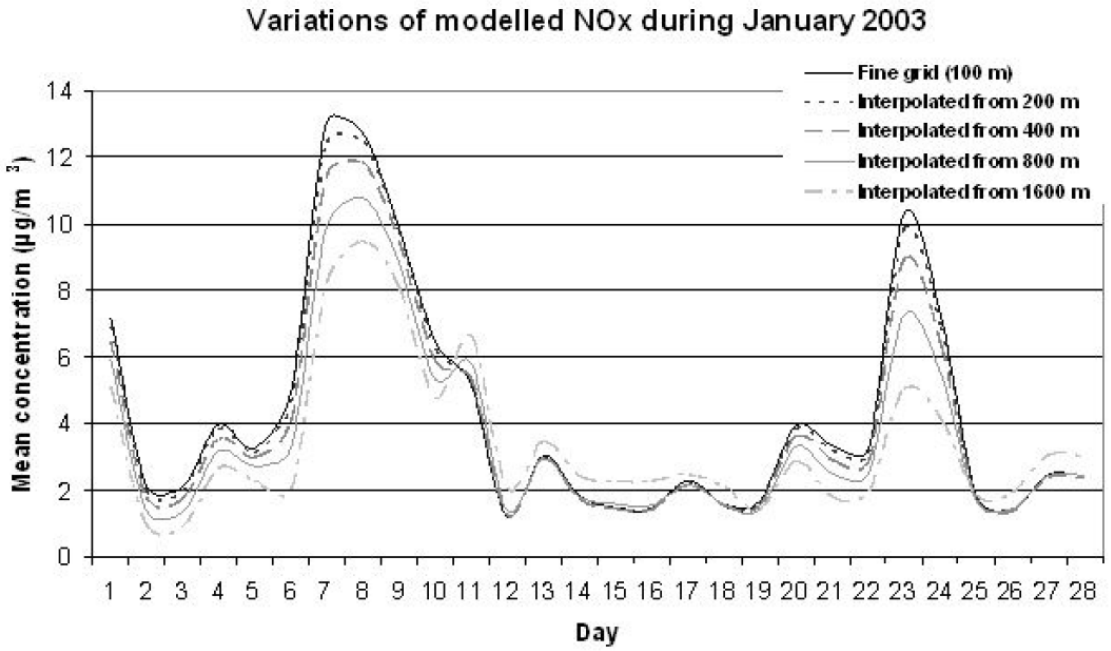

Figure 5. Time series of NOx concentrations (=g/m3) for different resolutions interpolated to100 metres by bilinear interpolation. The graph shows the mean value for all cells in the study area, urban Lund. From Stroh et al, 2007.

Exposure database (ExpDB)

The use and access to the exposure data for epidemiological studies is, in its current form, limited since the database is incorporated with the software ENVIMAN. This arrangement forces the user to set up and start a modelling session for each project separately, which is time consuming and causes delays. To ease access and use of the EDB for epidemiological studies we have formed a new **exposure database (ExpDB)** with already modelled concentrations of NO_x and PM for Scania. This database contains hourly concentrations with a spatial resolution of 250 metres in urban areas and 500 metres in rural areas (based on results from Stroh et al 2007). A new interface for handling the database is created, that will take lists of geographical locations and time periods as input. For time series, the program provides aggregated measurements, such as mean for the selected time period, daily mean and daily number of hours of exposure at different air pollutant levels.

Sustainability and dissemination

A sustainable solution for future updating of the EDB and for access to data for stakeholders in the society has been agreed with the regional and local authorities in Scania (länsstyrelse, kommuner, Skånes luftvårdsförbund). Emission data need to be updated with new information about emission sources and meteorology. These updates ideally should be done once each third to fifth year. A framework for such an update, and an agreement on responsibility for hosting and maintenance of the EDB has been arranged. This framework will also stimulate further stakeholder use of the database.

Main publications

Gustafsson S. Uppbyggnad och validering av emissionsdatabas avseende luftföroreningar för Skåne med basår 2001. Licentiate thesis 2007 from the Department of Physical Geography and Ecosystems Analysis, Lund University. Available at www.ymed.lu.se/papers/Susanna_Gustafsson_lic.pdf

Stroh E. The use of GIS in exposure-response studies. A regional study of air pollution and noise in southern Sweden. Licentiate thesis 2006 from the Department of Physical Geography and Ecosystems Analysis, Lund University Available at www.ymed.lu.se/papers/Emilie_Stroh_lic.pdf.

Stroh E, Harrie L. A study of spatial resolution in pollution exposure modelling. *Int J Health Geogr* 2007;6:19-.

Stroh E, Oudin A, Gustafsson S, Pilesjö P, Harrie L, Strömberg U, Jakobsson K. Are associations between socio-economic characteristics and exposure to air pollution a question of study area size? An example from Scania, Sweden. *Int J Health Geogr,* 4:30-43, 2005.

Friman K, Axmon A, Gustavsson S, Rittner R and Tinnerberg H. On the correlations between objective measurements of nitrogen dioxide and self reported distance to road, traffic intensity and air pollutant complaints. *Ongoing manuscript.*

Database B - Exposure to traffic noise

Summary description

Our existing traffic database, which includes road traffic only, for Scania is partly derived from the emission database with base-year 2001 described above, and partly from the national road data base (Nationella Väg DataBanken, NVDB). Currently, data on position and extension on all road segments in Skåne (around 160 000 segments) are included. Traffic count data, speed limit and number of vehicles, are available for all governmental road segments with measurements (approximately 16 000), and for approximately 4 000 segments administrated by the municipalities. For road segments without traffic data (including many small roads with low traffic intensity), representative values were assigned to each segment based on existing data. We have used a simplified version of the well-established Nordic prediction method for road noise [Bendtsen 1999], which included only noise reduction due to distance and ground type (soft or hard). The calculations were performed using in house developed programs and Arc View 3.3 and resulted in modelled equivalent ($L_{Aeq,24}$ and $L_{Day, Night\ (DN)}$) and maximal (L_{Afmax}) noise levels with a resolution of one dB(A).

A data set including the required data for modelling of noise from trains was produced in 2006 (Liljewalch-Fogelmark 2006).

Aircraft noise data are available for four airports in Skåne (Sturup, Ängelholm, Ljunbyhed och Everöd) (Ardö 2008). These traffic data require replenishing, updating, quality and consistency checks before they can be used for detailed noise exposure modelling.

Validation

The modelled noise levels are highly correlated with self-reported traffic noise disturbance in the population (Person et al, 2007 Bodin et al, manuscript), which indicates that the modelling works well on a relative scale.

However, an ongoing study in the city of Malmö (Albin et al, manuscript) indicates that current road noise estimates in the database are systematically higher than in a more detailed study using SoundPLAN, a state-of-the-art and dedicated noise calculation software (ÅF-Ingemansson AB 2007). Thus, a revised modelling is required, at least for urban areas. Such modelling is at now ongoing.

Reports

Ardö J. Trafik, människor och miljö i Skåne. Projektrapport till Naturvårdsverket. http://www.giscentrum.lu.se/miljodb/Buller_215_04.pdf

Liljewalch-Fogelmark K. Tågbuller i Skåne - befolkningens exponering. Seminarieuppsatser 125, Centrum för Geobiosfärsvetenskap, Naturgeografi och Ekosystemanalys, Lunds Universitet, 2006

Ardö, J. 2008. Skånsk Miljödatabas - uppbyggnad och kvalitetskontroll - projekt redovisning. Arbetsrapport, GIS-Centrum, Lunds Universitet, 36 pp.

Database C - Access to recreational values of the natural environment

Interview studies conducted 1995-2005 in landscape architecture/environmental psychology have revealed characteristics, recreational values, of urban open spaces that humans appreciate and that can be expected to be important for human health [Grahn et al, 2005]. We have recently established a database for five such recreational values, using objective definitions that were possible to implement with available ground cover data using GIS. The database covers Scania; however the central parts of the largest cities of the region, Malmö, Lund, Helsingborg and Kristianstad, are at present not mapped due to difficulties in obtaining data in urban environment. The main source for the mapping was the Corine mapping [Büttner et al 2002], conducted by The National Land Survey of Sweden (Lantmäteriet). Some of the other data used has been mapped in various governmental mappings, some of them onsite like the cultural heritage/antiquities mappings, and some mainly mapped through remote analysis. The characterisation was only done for Scania, but could easily be extended for use within all of Sweden as long as the same data sources also can be made available. If the database is extended to the inner areas of the four largest cities in Scania, then the importance of access to recreational values near the residence, e.g. through urban parks, for humans living in the urban environments could also be investigated.

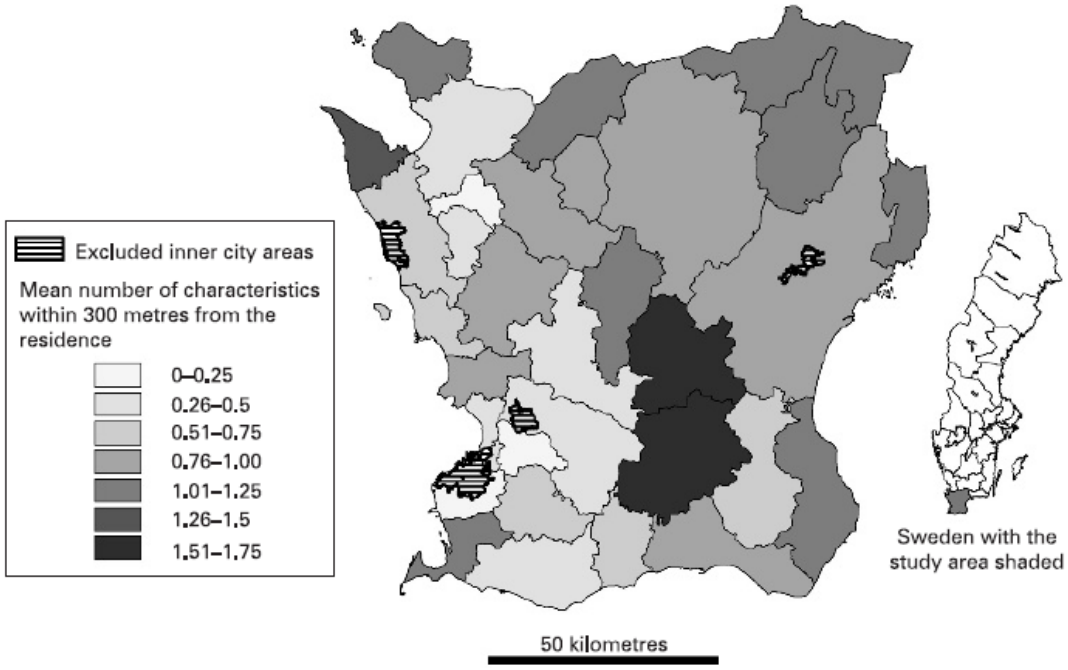

Figure 3. Mean number of recreational values of the natural environment within 300 metres distance from the residence in each of the 33 municipalities in the Scania region (range 0.08 for Staffanstorp municipality in the southwest to 1.68 for Hörby municipality in the middle of Scania). From: Björk et al. 2008

On average, a citizen of the Scania region, inner city areas excluded, had access to only 0.67 recreational values within a 300 metres distance from their residence (Björk et al 2008). The mean number of recreational values in the municipalities are given in Fig 3. We estimated that more than 70% of the study population had a natural neighbourhood environment either without any of the recreational values (58%) or with only the culture characteristic present (14%) within 300 metres distance. The proportions of individuals born in Sweden and living in their own houses were noticeably higher in residential areas where more than one of the five recreational values were present.

Validation

We are verifying the categorization of recreational values using a large sample from the general population (questions in a postal enquiery to 4000 referents in ongoing case-referent studies). Mapping of the hitherto unmapped central parts of four cities, and inclusion of the remaining three characteristics will be performed by coworkers at SLU, Alnarp. A combination with remote sensing and aerial photogrammetry will render a map with total coverage and good accuracy.

Publication

Björk J, Albin M, Grahn P, Jacobsson H, Ardö J, Wadbro J, Östergren P-O, Skärbäck E. Objective characteristics of the natural neighborhood environment in relation to physical activity, obesity, and well-being in a large public health survey. Journal of Epidemiology and Community Health, 2008;62 (4) E-pub.

Part 2. Health and well-being in relation to air pollution, traffic noise, and natural environments in Scania

The common aim of all the following population-based epidemiological studies is to determine dose-response associations between well-defined health outcomes and air pollution and/or community noise, with emphasis on emissions from traffic at exposure levels that are prevailing in Scania. Health promoting factors in the natural environment have also been investigated. We have used data from several existing population-based surveys and existing national registry information, supplemented with new postal enquirys.

Traffic-related air pollution associated with prevalence of adult respiratory disease. A cross-sectional study in 2000

Methods: Questionnaires from a previous population-based study [Montnémery et al 2007] in 2000 (n= 9319, age range 18-77 years) provided individual data about disease outcomes and self-reported traffic exposure. Geocoded residential addresses were linked to the Swedish Road Database and to a pollutant database for modelled annual means of NOx.

Results Living within 100m of a road with >10cars/minute (24 hr average) was associated with a higher prevalence of asthma diagnosis (OR= 1.40, 95% CI=1.04-1.89), and COPD diagnosis (OR=1.64, 95% CI=1.11-2.4) compared with having no heavy road within this distance. Self-reported traffic was also associated with diagnosis of asthma and COPD. For NOx (annual average), an association was only found for COPD diagnosis and current symptoms of asthma/bronchitis.
Further analysis showed that living within 100 m from a road with >10 cars/min (vs. no major road within 100m) was associated with a higher prevalence of asthma diagnosis triggered by allergic factors (OR=1.83, 95% CI= 1.28-2.62) and allergic rhinitis (OR=1.26, 95% CI=1.01-

1.58). No association was seen with asthma or rhinitis triggered by other factors. Living within 100m of a road also showed a higher prevalence of hand-eczema during the last 12 months (OR=1.63, 95% CI=1.19-2.23). Self-reported living close to a road with heavy traffic showed mainly consistent results, while modelled levels of NOx were not significantly associated with disease.

Conclusions: Living close to traffic was associated with diagnosed asthma/COPD, indicating that traffic related air pollution has long-term effects on chronic respiratory disease in adults. The effects were only seen for allergic, not non-allergic, asthma and rhinitis.

Publications

Lindgren A, Stroh E, Montnemery P, Nihlén U, Jakobsson K, Axmon A. Traffic-related air pollution associated with prevalence of asthma and COPD/chronic bronchitis. Across-sectional study in Southern Sweden. (Submitted)

Lindgren A, Stroh E, Nihlén U, Montnemery P, Axmon A, Jakobsson K. Traffic is a risk factor for allergic asthma, allergic rhinitis, and hand-eczema, in adults. A cross-sectional study. (Submitted)

Air pollution and adult asthma. A two-phase case-referent study in Scania.

Method: The sampling frame for this study was responders in Scania Public Health Survey 2004 aged 18-65 (N = 24 819; 59% participation rate) stratified on residential area (step 1). The case-control study (step 2) included 2856 respondents (86% response rate), 705 asthmatics and the rest controls (1:3) , frequency matched on gender. Residential- and work-place addresses were geocoded. The questionnaires contain information on general health, occupation, life-style, and activities in traffic environments, building characteristics, etc. Traffic exposure was estimated by GIS-based distance to roads, dispersion-modelled concentrations of NOx (annual mean, 250x250m grid), and self-estimates on traffic intensity. The statistical analysis, using a two-phase strategy [Oudin et al 2007] is presently under way.

Preliminary results (data from step 2): Living within 50m of a road with a traffic intensity of >10cars/min measured by GIS was associated with increased asthma diagnosis prevalence, with OR:2.1 (95% CI 1.0-4.5; adj. for sex, age, smoking, BMI, socio-economy, etc), compared to having no heavy road within this distance. For asthma symptoms the corresponding adjusted OR was 4.4 (2.1-9.2). Decreasing but still significant effects were seen for a heavy road within 100 and 250m of residency, while no effects were seen in relation to modelled NOx. Self-estimated daily time spent in traffic showed effect on asthma prevalence (adjusted OR: 1.4(1.0-1.9)) and asthma symptoms (adjusted. OR: 1.7(1.2-2.4)). No effects were seen from work-place exposure to traffic, or commuting time to and through work.

Conclusion: The preliminary results indicate that living close to roads with heavy traffic is a risk factor for asthma diagnosis and symptoms, are preliminary. Selective participation may however affect the estimates. The two-phase analysis, which is under way, will give additional information.

Publication

Lindgren A, Stroh E, Björk J, Jakobsson K. Asthma in relation to residential and time-activity dependent exposure to traffic. A two-phase case-control study (Manuscript).

Ischemic stroke. A registry-based case-referent study in Scania

Methods: First-time ischemic strokes in Scania between 2001 and 2005 in persons born between 1923 and 1965 were obtained from RiksStroke (N = 4 904). Population controls (N = 5 333), matched on age, sex and municipality were collected from Scania Public Health Survey 2004 (N = 24 819; 59% participation rate). Geocoded residential addresses were linked to our ExpDB for modelled annual means of NO_x.

In a second step, a new set of are selected from the population registry in Scania. In-dept questionnaires are sent to cases and controls during September 2008. A two-phase analysis will follow. The efficiency of such a methodology has been evaluated thoroughly.

Preliminary results (step one): A statistical significant association between residential outdoor annual mean level of NO_X to NO_X and ischemic stroke was present. An increase in NO_X of 10 $\mu g/m^3$ was associated with an OR of 1.2, (95 % confidence interval 1.1-1.4), adjusted for smoking, diabetes, medication for hypertension, birth country, educational level in parish, and marital status. The effect estimates of NO_X on ischemic stroke risk increased with age but were similar between men and women.

Conclusions: The results are preliminary. The participation in the Public Health Survey is differential with respect to educational level and origin of birth, i.e. socioeconomic determinants that have been shown to be correlated to environmental levels of NO_X in Scania. Hence, we suspect that the exposure levels among the controls may be lower than in the overall population. Further analyses to elucidate this are under way.

Publications

Oudin A, Björk J, Strömberg U. Efficiency of two-phase methods with focus on a planned population-based case-control study on air pollution and stroke. Environmental Health 2007, 6:34-.

Oudin A, Stroh E, Strömberg U, Jakobsson K, Björk J. Exposure to air pollution and ischemic stroke in Scania, Sweden. *Manuscript, presented at mid-seminar, March 2008*

Road traffic noise in southern Sweden and its relation to annoyance, disturbance of daily activities and health.

Methods: A large public health survey in southern Sweden in 1999-2000 supplied data (N=13 557; 54% participation rate) on the demography, annoyance, and disturbance of daily activities, and on general health problems regarding concentration, sleep, stress, and treatment for hypertension. Residential road noise exposure was assessed with GIS. Associations with 24-hour equivalent (average) and maximum road noise level were investigated for all participants and for selected subgroups

Results: Annoyance from road traffic noise and the disturbance of daily activities increased markedly with road noise exposure. More than 25% reported at least occasional disturbance from traffic noise during relaxation and sleep in the highest exposure category for each noise measure. No overall pattern between road noise exposure and general health problems emerged. Among the participants that reported annoyance from road traffic noise (N=623), the average road noise level was significantly associated with concentration problems and with treatment for hypertension. Positive associations between average road noise exposure and health problems were found among females (hypertension), persons born outside Sweden

(sleep), the unemployed (stress), and participants that reported financial problems (concentration problems).

Conclusions: Exposure to road traffic noise at high levels was common and produced frequent disturbances of daily activities. Negative health effects from road traffic noise were observed in important subgroups. The findings are of concern for southern Sweden, as well as for other regions with similar or higher traffic intensity.

Publications

Björk J,Ardö J , Stroh E, Lövkvist H, Östergren PO, Albin M. Road traffic noise in southern Sweden and its relation to disturbance of daily activities, annoyance, and health. Scand J Work Env Health, 32:392-401, 2006.

Trait anxiety and GIS-modeled exposure as determinants of self-reported annoyance to noise and other environmental factors in the home

Method: A trait anxiety scale was introduced in a cross-sectional public health survey with 2856 respondents (see Lindgren et al 2008c). Of these, 705 had self-reported asthma and the rest constituted gender-matched referents. Annoyance to 10 specific factors in the residential environment, mainly focusing on source specific noise and air pollution, was assessed. LAeq,24 as well as annual average NOx levels (µg/m3) at the residential address were modelled with high resolution, using a road data base and a detailed emission data base for NOx.

Results: The two most prevalent complaints were annoyance to traffic noise and sounds from neighbours, which was reported of about 8 % of the participants. Unadjusted logistic regression analyses using the continuous trait anxiety score as a predictor showed positive associations with ratings of annoyance from total traffic noise, sounds from neighbours, sound from ventilation, exhaust fumes from traffic, sounds from other installations, and vibrations from traffic (OR's between 1.37 to 2.14). Modelled noise and NOx exposure were positively related with annoyance to traffic noise and exhaust fumes, respectively. Adjustment of the trait anxiety scores for other individual characteristics and potential determinants did not change the overall pattern of results.

Conclusion: Annoyance ratings to noise, air pollution and other common environmental factors in the home environment could be considered to mirror personality disposition in terms of habitual anxiety level and, when appropriate, objectively modelled noise and NOx

Publication

Persson R, Björk J, Ardö J, Albin M, Jakobsson K. Trait anxiety and modeled exposure as determinants of self-reported annoyance to sound, air pollution and other environmental factors in the home. *Int Arch Occup Environ Health* 2007;81:179-191.

Mental distress and modeled traffic noise exposure as determinants of self-reported sleep problems

Methods: Data from Scania Public Heatlh Survey 2004 was used.. All 11 629 persons that were occupationally active, employed at least half-time and not having used sleep medication within the last 3 months were selected for analysis. The outcome was sleep problems in general, and sleep problems attributed to nocturnal traffic noise. Mental distress was assessed in relation to work, financial problems, self-rated health, and factors in private life. Because

we had no information on when people went to bed or awoke, night time noise exposure was estimated by using modelled A-weighted energy equivalent continuous sound pressure levels during a full day (24 hr; $L_{Aeq,24}$) at the residential address.

Results: Traffic noise exposure was significantly associated with sleep disturbances attributed to traffic noise, with OR 1.04 95% CI 1.03-1.05) per unit increase of LAeq,24, adjusted for gender, age, marital status, and type of residence. Traffic noise exposure was not associated with sleep disturbances in general. Several measures of mental distress also showed to be significant predictors of disturbed sleep attributed to traffic noise, as well as of general sleep disturbances.

Conclusion: The results confirm previous findings that traffic noise exposure as well as perceived psychosocial working environment contribute to disturbed sleep. Our analysis did not confirm our hypothesis that distress due to work stress will increase the propensity to wake up or to feel disturbed by traffic noise when trying to sleep.

Publication

Kristiansen J, Albin M, Ardö J, Björk J, Jakobsson K, Stroh E, Östergren P-O, Persson R. Mental distress and modeled traffic noise exposure as determinants of self-reported sleep problems. In Proceedings of the 9th Congress of the International Commission on the Biological Effects of Noise 2008 (Editor B. Griefahn), ISBN 978-3-9808342-5-4, p. 489-95.

Recreational values of the natural environment in relation to neighbourhood satisfaction, physical activity, obesity and wellbeing

Methods: Data from Scania Public Health Survey 2004 (N = 24 819; 59% participation rate) were used. Geocoded residential addresses and GIS were used to assess objectively five recreational values of the close natural environment: serene, wild, lush, spacious and culture.

Results: On average, a citizen of the Scania region, inner city areas excluded, only had access to 0.67 recreational values within 300 metres distance from their residence. The number of recreational values near the residence was strongly associated with neighbourhood satisfaction and physical activity. The effect on satisfaction was especially marked among tenants and the presence of recreational values was associated with low or normal body mass index in this group. A less marked positive association with vitality among women was observed. No evident effect on self-rated health was detectable.

Conclusions: Immediate access to natural environments with high recreational values was rare in the study population and was distributed in an inequitable manner. Moreover, such access was associated with a positive assessment of neighbourhood satisfaction and time spent on physical activity, which can be expected to reduce obesity and increase vitality by having a buffering effect on stress.

Publication

Björk J, Albin M, Grahn P, Jacobsson H, Ardö J, Wadbro J, Östergren P-O, Skärbäck E. Objective characteristics of the natural neighborhood environment in relation to physical activity, obesity, and well-being in a large public health survey. *Journal of Epidemiology and Community Health*, 2008;62

Road traffic noise and hypertension

Methods: A total of 11 833 individuals between 35 and 65 years of age participating in Scania Public Health survey 2004 were included in this study (Bodin et al 2008). Hypertension was defined as consistent self-reported pharmacologically treated hypertension, using two questions in the survey. Using our databases, we estimated the day-night average A-weighted road traffic noise exposure [LAeq 24hr (dB)]. We adjusted for age, sex, BMI, alcohol intake, exercise, education and socioeconomic group in the statistical analysis.

Preliminary results: An approximately linear relation was found between hypertension and LAeq 24hr (dB) when using 5-dB groups (<40; 40-44; 45-49… >60). Sub-group analysis showed an elevated risk for hypertension associated with a 5-dB increase of exposure for women (OR 1.06; 95%CI 1.00-1.12) following a log-linear relation, but no such relation could be found for men (OR 1.00; 95%CI 0.96-1.07). Stronger association was also suggested for those born in a foreign country, and those experiencing that traffic noise interfered with their sleep or rest.

Conclusion: Preliminary results suggest that road traffic noise may increase the risk for hypertension. Confirming analyses taking into account potential selection bias are presently under way.

Publication

Bodin T, Björk J, Albin M et al. Associations between road traffic noise and high blood pressure. Manuscript.

Annoyance, stress and hypertension in relation to noise exposure from road traffic and railroads. A crossectional study in Malmö.

Björk J, Albin M m.fl. Hypertension in relation to noise exposure from road and train traffic in the city of Malmö. *Manuscript.*

Albin M, Björk J, m fl. Disturbance of daily activities from road and train traffic in the city of Malmö. *Manuscript.*

Methods: A questionnaire on noise from road traffic, railroads, aviation and other sources, annoyance to air pollution, residency characteristics, occupational noise exposure, and socioeconomic and life-style background variables, and health was sent to 5600 adults in Malmö in 2007. The response rate was 55%. A very detailed noise exposure modelling has been performed.
Results: The data analysis is ongoing, with emphasis on evaluation of dose-response relationships for different sources of noise. The marked socioeconomic segregation within Malmö will allow analysis of effect modification of socioeconomic status.

Birth weight, gestational length, stillbirths and perinatal death.

Method: Information about all 84035 deliveries in Scania 1999-2005 was obtained from the Medical Birth Register (MBR) including background characteristics (e.g. maternal age, weight, height, smoking habits and occupation) as well as for the delivery outcomes (gestational length, gender, single/multiple births, birth weight, birth length, perinatal deaths and malformations). The maternal residential address is geocoded, and linked to our exposure databases. The main exposure metric is maternal exposure to different air pollutants (PM2.5, PM10, NO_2 and NO_X) expressed as average levels and maximum levels for different time windows (trimesters), and time over a certain level. Also, the proximity to roads with certain traffic intensity is determined.

Results: Data analysis is ongoing. The almost total coverage of MBR with prospectively available data on important covariates, and high-resolution exposure assessment makes this study unique in an international perspective.

Part 3. Cost of illness (COI) of air pollution

The aim of this part of the project is to provide a critical and systematic review of the societal costs of air pollution related ill health (CAP), to explore methodological issues that may be important when assessing or comparing CAP across countries and to suggest ways in which future CAP studies can be more useful for policy analysis. The methodology includes a systematic search based on the major electronic databases and the websites of a number of major international organizations. Studies are categorized by origin - OECD countries or non-OECD countries - and by publication status. Seventeen studies are included, eight from OECD countries and nine from non-OECD countries. A number of studies based on the ExternE methodology and the USA studies conducted by the Institute of Transportation are also summarized and discussed separately. The present review shows that considerable societal costs are attributable to air pollution-related health hazards. Nevertheless, given the variations in the methodologies used to calculate the estimated costs (e.g. cost estimation methods and cost components included), and -country differences in demographic composition and health care systems, it is difficult to compare CAP estimates across studies and countries. To increase awareness concerning the air pollution-related burden of disease, and to build links to health policy analyses, future research efforts should be directed towards theoretically sound and comprehensive CAP estimates with use of rich data. In particular, a more explicit approach should be followed to deal with uncertainties in the estimations. Along with monetary estimates, future research should also report all physical impacts and source-specific cost estimates, and should attempt to estimate 'avoidable cost' using alternative counterfactual scenarios.

Publication

Pervin T, Gerdtham U-G, Lyttkens CH. Societal costs of air pollution-related health hazards: A review of methods and results. *Cost Effectiveness and Resource Allocation*, in press 2008

Important research collaborations, directly related to, or emerging from the present EMFO project

- "The micro-perspective on air pollution": Experimental investigations on lung deposition and physiological responses (lung function, biomarkers for inflammation in nasal lavage and exhaled breath condensates, heart rate variability) after controlled exposures to ultra-fine particles (Professor Bo Jönsson and coworkers, Occupational and Environmental Medicine (OEM), Lund, Prof Mats Bohgard and coworkers, Ergonomics and Aerosol Technology (EAT), Faculty of Engineering (LTH), Lund University)
- "The micro-perspective on the interplay between air pollution, noise and psychological stress": Experimental investigations on lung deposition and physiological responses (lung function, biomarkers for inflammation in nasal lavage and exhaled breath condensates, heart rate variability, neuropsychological tests) after controlled exposures to diesel particles, noise and psychological stressors (Anders Gudmundsson and coworkers, EAT, LTH, Ass prof Kai Österberg, OEM Lund).
- "Lund University longitudinal cohort (LULOC)". In our projects, we are reusing data from several previously performed population-based surveys in Scania. This has proven

a very valuable resource of a kind that could be used by many other researchers. This experience was the driving force when the LULOC initiative for strengthening of infrastructure for epidemiology at Lund University was elaborated. A large prospective cohort, LULOC, aggregated from existing population--based crossectional studies, with a basic common set of prospectively collected individual base-line information, and with a follow-up period of 5-15 years will be created. The subjects will be geocoded at residential addresses (coordinates) each year, thus enabling linkage to environmental and societal area level data from other sources. Our own elaborated resources for spatial epidemiology will be incorporated into this infrastructure as openly available environmental databases, and as tools for mapping of health events. The development of this infrastructural resource at Lund University, which has been funded by VR-KFI will be performed in close contact with the Swedish National Data Service (SND) initiative.

- ", EUROHEIS2"
  We are partners in a European collaboration, EUROHEIS2, in which innovative IT tools for health threat analysis (the Rapid Inquiry Facility (RIF) are elaborated in cooperation with US CDC Environmental Public Health Tracking Program [www.euroheis.org]. The RIF incorporates advanced GIS techniques and spatio-temporal analysis of routinely collected health data and environmental data. The RIF is able to produce long-term risk assessment in relation to specified pollutants, by analysis of health events in selected areas or buffer zones around point sources, or by other types of spatially located exposure variables. The RIF also incorporates measures of socioeconomic status (level of deprivation) as a means of partially accounting for confounding area influences on health. The RIF was originally designed to handle data in small area units, which is available in most European countries. The RIF is now extended to enable the use of individual level data in Sweden. We will add our air pollution database, the noise data base, and road data to the RIF system. Our specific task within EUROHEIS2 collaboration is to explore the effects of spatial aggregation of outcome and exposure data. This is performed using results from the studies in **Part 1 and 2** (see above).
- The project group is strongly linked to the FAS-centre of excellence METALUND and its research school **(**http://www.med.lu.se/forskning/starka_forskningsomraaden). METALUND integrates the expertise at Occupational and Environmental Medicine and Ergonomics and Aerosol Technology (LTH) and is one of the nine Strong Research Environments at Lund University.
- We are partners in LISTENING LUND (Ljudmiljöcentrum) at Lund University http://www.ljudcentrum.lu.se/lyssnande-lund/aktuellt Listening Lund arranges seminars, publish scientific reports and a newsletter and has regularly contacts with industry (vehicles, tyres, absorbents). In 2007, LISTENING LUND was awarded by the Swedish Society of Acoustics (http://www.akustiska-sallskapet.org/home/news.asp?sid=5684&mid=3&NewsId=24568&Page=1)

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