TØI Working Report
1173/2000

Towards a national indicator for noise exposure and annoyance

Part II: Mapping changes in noise annoyance to monitor the efficacy of noise reduction efforts

Ronny Klæboe
Torkel Bjørnskau

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Title: Towards a national indicator for noise exposure and annoyance. Part II: Mapping changes in noise annoyance to monitor the efficacy of noise reduction efforts

Author(s): *Ronny Klæboe; Torkel Bjørnskau*

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Summary:
From a noise exposure mapping at the national level established by Statistics Norway, a system for charing changes in noise annoyance is sketched. By means of noise neighbourhood modelling and stratification of Norway, 40+ representative study areas are selected. The results are analysed by means of a mulltilevel hierarchic structural level exposure-effect model. such models take care of both the effects of noise exposure and factors associated with inter-area differences. Establishing measurement instruments and controlling for modifying factors ensure that the effect of noise exposure changes on noise annoyance can be assessed and the efficacy of noise abatement efforts to be monitored.

Tittel: Kartlegging av endringer i støyplage for å anslå effekten av støytiltak

Forfatter(e) *Ronny Klæboe; Torkel Bjørnskau*

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TØI har utarbeidet et opplegg for å kartlegge støyplage på basis av en nasjonal kartlegging av støyeksponering ved bolig utarbeidet av SSB. På basis av en hierarkisk flernivå struktur modell foreslås det å utarbeide en generell formel for støyplage som funksjon av støyeksponering som også tar hensyn til forskjeller mellom ulike by og tettsteds-områder og andre modifiserende faktorer. Av sammenhengene vil det være mulig å skille mellom effektive og ineffektive støytiltak, endringer i befolkningen som skyldes endringene i støyeksponering og endringer som skyldes endringer folks holdninger og andre faktorer som kan påvirke utviklingen i støyplage over en 10 års periode.

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Gaustadalleen 21, NO 0349 Oslo
Telephone +47 22 57 38 00 - www.toi.no

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Telefon 22 57 38 00 - www.toi.no

Preface

This working document is the second of two reports describing a project undertaken for the The Research Council of Norway by Statistics Norway and the Institute of Transport Economics. The purpose of the project was to sketch a system for the systematic monitoring of noise emissions, noise exposure and noise annoyance with special considerations to capturing changes over time.

The first report is a report authored and published by Statistics Norway. In their report a system to monitor noise emissions along the Norwegian road net and calculate a simple measure of the noise exposure at all affected dwellings is described.

In this, the second report, the noise mapping and exposure calculations are linked to socio-acoustic surveys monitoring noise annoyance and changes in noise annoyance for 40+ areas representative of Norwegian noise environments. By focusing on a smaller set of areas that are representative for Norway it will be possible to describe changes in the traffic situation, noise abatement measures and more detailed information on whether some noise abatement measures are more effective than others in reducing noise. The methodology utilises modern Geographical information systems (GIS), the availability of digital maps and other geographical information just recently made available. At the same time sampling statistics are used too provide the national figures with high quality and minimum cost.

To ensure that the analyses of the relationships between the perception of noise and the changes in noise annoyance over time are not confounded by changes in modifying factors over a 10 years period, a separate part of the project is to develop tools for measuring relevant attitudes, expectations, sensitivities, urban dynamics and other modifying factors.

The working report is written by Dr. Polit. Torkel Bjørnskau and Chief Research Officer Ronny Klæboe. They have benefited from discussions with Dr. Kristin Rypdal, Gisle Håkonsen, Per Schøning and Svein Erik Stave from Statistics Norway. Secretary Jannicke Eble has helped with the text, production and layout of the working document.

Oslo, December 2000
TRANSPORTØKONOMISK INSTITUTT

Marika Kolbenstvedt
Head of Department

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TØI working report 1173/2000
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Summary:

Mapping changes in noise annoyance to monitor the efficacy of noise reduction efforts

This paper describes a system for connecting the noise exposure mapping proposed by Statistics Norway to socio-acoustic studies in a set of 40+ study areas that are representative for Norwegian noise neighbourhoods. Work in order to establish measurement instruments for factors that may significantly modify the relationships between exposure and annoyance are also described..

The end result of the modelling effort is a mapping of changes in noise annoyance that is representative for the Norwegian population. When related to information on noise exposure and controlling for modifying factors and inter-area differences are taken into account it will be able to ascertain which noise combat techniques work and which that don't. It will also be possible to decide how far the national efforts go in attaining the target of a 25% noise annoyance reduction in Norway before 2010.

The system proposed by Statistics Norway and the Institute of Transport Economics makes heavy use of geographical information systems for performing spatial analyses and providing a stratification of Norway in different types of noise neighbourhoods. Both the technology itself and the data necessary to implement the strategic noise annoyance mapping system, has recently become available. The system is innovative not only in a national sense but also with respect to the efforts undertaken in Europe to chart changes in health relevant exposure and effect indicators.

A stratification of Norway in noise neighbourhoods is achieved by the spatial algorithms. The stratification provides the basis for extracting a sample of 40+ sub-areas that are representative for Norway. Establishing such a set of sub-areas allows for more qualified noise exposure modelling for instance by SINTEF. Use of a representative sample of sub-areas translate into substantial reduced costs in tracking changes in noise exposure in Norway over time

The national representative sample of noise neighbourhoods (the 40+ sub-areas) will by means of statistical sampling methods provide simple indicators of noise exposure, noise annoyance, changes in noise emissions, the extent of noise abatement measures being implemented and the resulting changes in noise exposure and noise annoyance for the whole of Norway. These results will follow from simple extrapolations from the representative sample and survey results to the whole of the population. In addition to the extrapolation of data by sampling statistics, it will also be possible to produce high quality exposure-effect relationships relating noise exposure and noise annoyance.

The working report can be ordered from:
Institute of Transport Economics, PO Box 6110 Etterstad, N-0602 Oslo, Norway
Telephone: +47 22 57 38 00 Telefax: +47 22 57 02 90

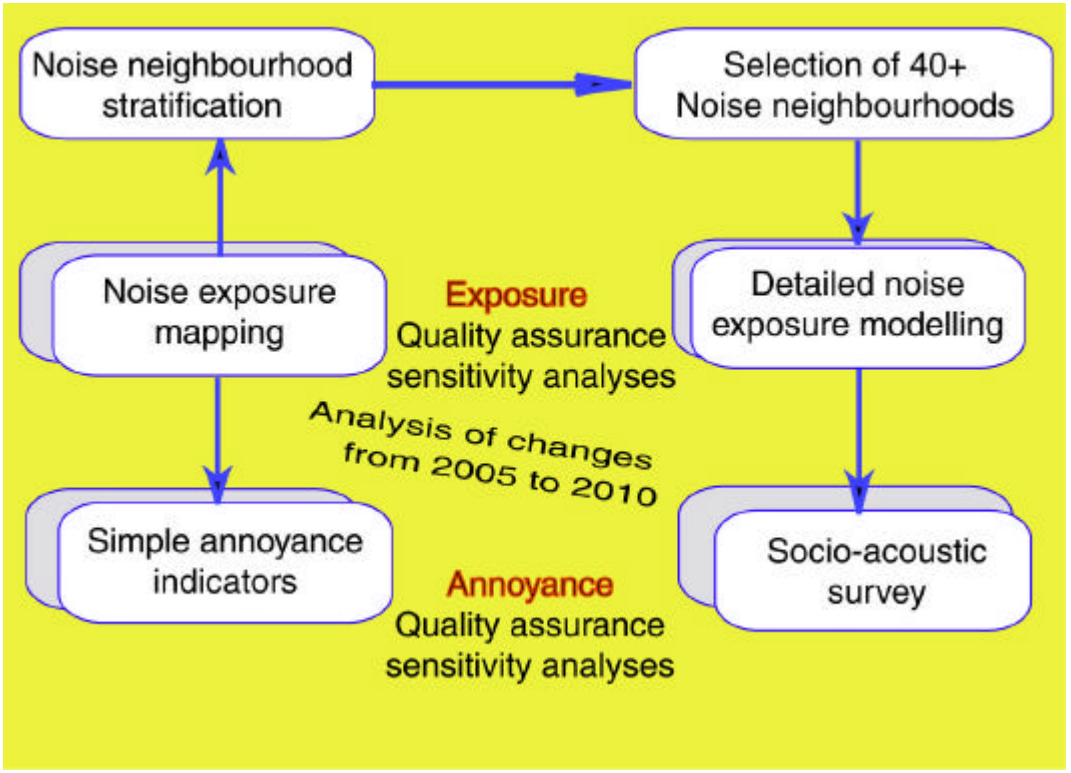

Figure S.1: Schematics of the Noise exposure-noise annoyance mapping system for Norway. As socio-acoustic surveys are costly, we have described a comparison of two surveys 5 year a part.

This multi level hierarchical structural equation modelling effort will be able to take into account differences between urban and rural areas, areas with multiple exposures contra single pollutant situations etc. This uniform, but at the same time flexible system is achieved by making use of multilevel structural equation modelling techniques. Such models seek to simultaneously account for both inter-area and within-area differences in noise annoyance and generate one general model that adapt a general exposure-effect relationships to the type of urban area it is applied to, while still making full use of information on noise exposure and modifying factors.

Changes in noise annoyance may be the result of changes in attitudes, the type of noise abatement efforts implemented, expectations of noise reductions and urban socio-dynamic processes triggered by changes in the environmental quality of urban areas. A project to establish suitable measurement instruments for attitudes has therefore been proposed. By controlling for possible modifying factors it should be possible to extract information that show the more causal relationships between noise exposure and noise annoyance and assess the efficacy of the noise abatement policies of the Norwegian authorities, and whether some policies are more effective than others in reducing noise annoyance.

1 Introduction

1.1 National target set as a reduction in noise annoyance

The governmental white paper on environmental issues (St. meld. nr. 8 1999-2000) has formulated as a target for noise reduction efforts that noise annoyance in Norway is to be reduced by 25 per cent within the year 2010 using the 1999 annoyance levels as baseline. The target is thus formulated in terms of changes in annoyance and not as a reduction in exposure. This is as it should be. Irrespective of the amount of money spent or the extent of noise reduction measures being undertaken by the public authorities, the success of noise abatement policies will ultimately be measured by their success in reducing noise annoyance in Norway.

1.2 National exposure effect curves are lacking

While there have been many local environmental surveys, there has not been a representative survey for Norway resulting in national exposure effect curves for transportation noise. There are therefore no national exposure-effect curves to apply. It has been suggested that one should adapt the mean response of a set of internationally derived exposure-effect relationships for Norway. This disregards both the question of how well such a European average fits the average relationship in Norway, and the variability for instance between rural and urban areas in Norway.

Current research in Norway (Gjestland 1998, Klæboe & al 1998) suggests that both for aircraft noise and for road traffic noise, it is necessary to use different exposure effect relationships for different regions/situations. For rail traffic there has been no attempt to derive exposure effect curves that are representative for Norway.

1.3 Noise reduction is not the same as annoyance reduction

In addition to the problems of establishing exposure effect relationships there are important problems in interpreting exposure-effect curves as descriptive of causal relationships as described by Klæboe (2000a). In particular exposure-effect curves describing static correlational relationships should not be interpreted as describing the effects of a noise reduction (an intervention). In the noise research literature (Raw and Griffiths 1990; WHO 1999) the failure of predicting changes in noise annoyance from changes in noise exposure is known as a paradox and has been the target of much research – see (Klæboe & al 1998).

Nonetheless, the initial plans to combat noise in Norway rely on such steady state exposure-effect relationships for estimating the effect of noise reduction efforts on

changes in annoyance and indirectly the cost-efficiency and benefit according to cost benefit analyses (SFT 2000). It is however important to know whether some types noise abatement efforts are more effective than others in reducing noise annoyance. Using reduction in noise annoyance as a yard stick also ensures a distinction between noise reduction measures that only reduces one aspect of exposure to road traffic to measures that have multiple effects. Klæboe (1998; 2000) has proposed that the reduction in annoyance can be greater for traffic reduction efforts having multiple effects than for noise abatement efforts only reducing noise.

Mapping changes in noise annoyance and not only changes in the exposure to transportation noise, ensures that it is possible to estimate the actual effects of different noise reduction efforts on annoyance and the cost efficiency of the measures with respect to noise annoyance reduction and not only noise reduction. This may again be used for altering the priorities between different types of noise reduction efforts.

1.4 The need for a national framework for assessing changes in annoyance

There is therefore a need to map changes in noise annoyance in Norway in such a way that it is possible to assess the effect of noise abatement strategies. If such a scheme is to work, it is necessary to provide a framework that can adapt to the differences in noise annoyance seen in different types of town areas. It follows that the framework should be capable of modelling the inter-area differences so that one does not have to establish a different set of exposure effect curves for each and every town area in Norway.

Another concern is that changes in important modifying factors do not disturb the relationships between noise exposure and noise effects too much. There is a range of possibly modifiers (see chapter 3) that may have a substantial impact over a 10 year period.

1.5 A national framework for mapping changes in exposure, modifying factors and annoyance

As a response to the challenge of establishing a national framework for monitoring changes in noise exposure, in noise annoyance and modifying factors, the Institute of Transport Economics (TØI) has as an ambition together with Statistics Norway to provide a complete system. The design of this system is described in chapter 2. The system augments the simple charting of noise exposure in Norway proposed by Statistics Norway with a mapping of changes in modifying factors in the population, changes in the associated noise annoyance and changes in other important effects of noise exposure at peoples' houses.

This system will provide the means of establishing exposure effect relationships for the whole of Norway that are locally adapted to different types of noise-neighbourhoods.

The system seeks to combine simplicity with quality assurance – providing rapid output that also serves as input to successive improvements. While initial measures of noise annoyance can be simple, use of infrequent high quality surveys will add meaning to simpler correlational relationships, and enhance the possibility of obtaining better causal exposure-effect models. The first implementation is meant to be of immediate use for mapping road traffic noise. It should however be possible to add railway noise without much additional work at a later stage.

1.6 The framework must be able to assess the effect of changes in modifying factors

Noise annoyance in the "black spots" of Europe is predominantly a function of noise exposure. In such areas there is little to be gained by charting attitudinal dimensions of annoyance. However, the current ambition is a noise policy for Norway and Europe looking also at the effects of noise exposure in the "grey areas" characterised by intermediate noise levels. For such studies the actual noise exposure has a lesser direct impact and modifying factors become more important. Modifying factors may be attitudes towards transport, towards the environment, towards the authorities etc. Such factors may play a more prominent role when the issue is annoyance at intermediate noise levels, than when it is the question of one's annoyance to the noise of an old jet taking off in the immediate vicinity.

As only 25% of the variation in peoples' reactions towards noise are explained by the actual noise exposure, it is evident that important changes in modifying factors may have a profound impact on noise annoyance. Possible changes in modifying factors within the 10 year noise reduction period, may result in a lack of correlation between changes in noise exposure and noise reactions:

- Noise annoyance may rise in spite of the large sums of money invested in noise abatement measures. In that case it is important to investigate the efficacy of the noise abatement efforts. Either the noise abatement efforts have been unsuccessful in reducing annoyance and thus should be amended, or they have been successful, but not sufficiently so to counteract other changes affecting people’s annoyance. The increase in annoyance would thus have been greater if the noise abatement efforts were not implemented, and the conclusion would be to promote noise abatement efforts further.
- In the cases where noise annoyance in the population is reduced, it is also important to know whether this is the result of the national effort to reduce noise, or whether the change in people’s annoyance only reflects changes in how environmentally conscious people are, or other attitudinal factors.

In chapter 3 we describe different types of attitudinal changes that may affect people’s annoyance with noise within a 10 year period.

2 Design of the system

2.1 Overview

The system proposed by Statistics Norway and the Institute of Transport Economics makes heavy use of geographical information systems for performing spatial analyses for both establishing a noise exposure measure and providing a stratification of Norway in different types of noise neighbourhoods.

Both the technology itself, the digital maps, the road maps, and building data with coordinate information necessary to implement the strategic noise annoyance mapping system has only recently become available. The system is innovative not only in a national sense but also with respect to the efforts undertaken in Europe to chart changes in health relevant exposure and effect indicators.

The starting point, stage 1, of the system is the noise exposure modelling performed by Statistics Norway (SSB 2000). The system for charting noise exposure from Statistics Norway will provide a simple noise exposure measure for each dwelling[1] in the whole of Norway.

Stage 2 consists of using the exposure data from Statistics Norway to build contiguous noise neighbourhoods allowing Norway to be stratified with respect to noise neighbourhoods[2].

On the basis of such a stratification it will, in stage 3, be possible to use sampling techniques to draw a sample of say 40+ neighbourhoods that are representative for Norway. The relatively large number of neighbourhoods have been chosen in order to be able to model inter-area differences explicitly in a hierarchical two-level exposure-effect structural equation model.

In stage 4 we propose a national socio-acoustic survey in these 40+ sub-areas where noise annoyance and other reactions to noise are mapped while at the same time controlling for modifying factors.

We propose in stage 5 that the simplified noise exposure mapping for the respondents that are sampled from each of these areas, are compared with more sophisticated noise mappings of the chosen representative areas[3], and adjusted where necessary. Use of databases over noise exposure for buildings along major highways and railroad stretches may provide local adjustment factors to the Statistics Norway algorithms.

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[1] Inititally there will be some white uncharted areas (municipal roads with inadequate data), that may have to be dealt with separately.

[2] It may also be convenient to stratify with respect to area type (Major city, other city areas, other), and by ground conditions in order to take into account the modifying effect of possible vibrations.

[3] Not neccesarily all areas

In stage 6 the results of the survey-part of the socio-acoustic study are analysed relative to the modified national exposure data (possibly with a recalculation of noise neighbourhood data). These analyses will provide national exposure effect relationships for the whole of Norway.

As the 40+ sub-areas are representative for Norway, they should also be able to reflect the impact of the national efforts undertaken to reduce noise both with regard to noise exposure, and noise annoyance. As socio-acoustic surveys will be costly, they should only be repeated say each 5th or 10th year. Ideally, part of the survey sample should agree to take part in a panel so that the same persons are asked about their noise annoyance at two different points in time and also about how they perceive that the noise situation has changed, what they think of different types of efforts etc.

It should be far easier to monitor changes within 40 such areas than establishing a complete inventory of everything that is done. The different stages have been illustrated in Figure 1. More details of the different stages are described in the following sections.

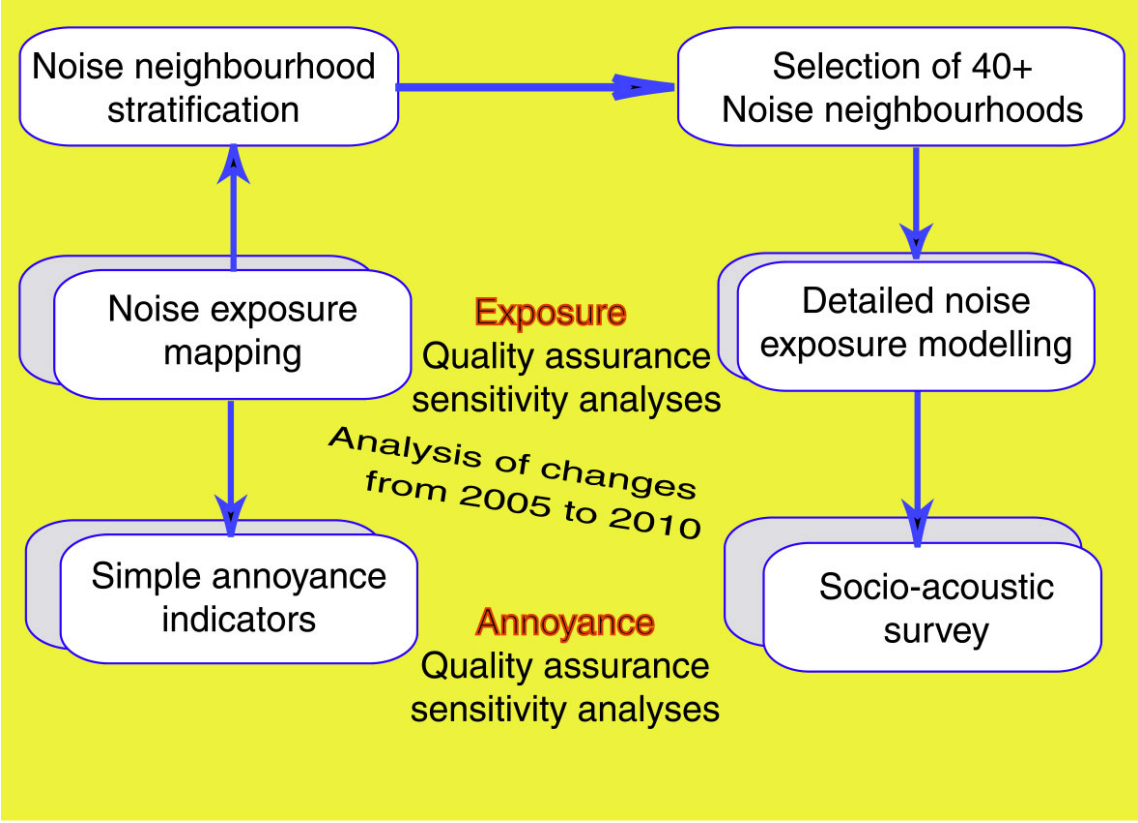

Figure 1: Schematics of the Noise exposure-noise annoyance mapping system for Norway. As socio-acoustic surveys are costly, we have described a comparison of two surveys 5 year a part.

2.2 Stage 1: Establishment of a noise exposure measure for each dwelling

This part of the project is described by Statistics Norway and will not be repeated here.

2.3 Stage 2: National stratification and map of urban soundscapes

We propose work with GIS-based spatial routines to build contiguous neighbourhoods on the basis of noise level and soundscape information, in co-operation with Statistics Norway. Statistics Norway has experience with work in developing routines for defining industrial areas, commercial areas etc. Such areas have in common that they include buildings that have different characteristics, but where it none the less is possible to extract the main characteristic of an area. In the first phase of this project the algorithms will assume that the whole neighbourhood has been mapped.

The algorithms will be adapted to the simple noise exposure model developed by Statistics Norway. This may result in simpler algorithms - or the addition of extra information to the noise exposure mapping.

As the development of the algorithms are more a question of finding suitable procedures than is a problem of coding or programming, the results of these efforts should be easy to adapt to other noise mapping efforts.

When connected to a national noise mapping of dwellings as proposed by Statistics Norway, this will result in a mapping of the different urban neighbourhood Soundscapes of Norway.

Such maps will provide information about important differences in the sound quality of different parts of urban areas, and in some cases provide important insights in possible efforts in order to improve local situations. This is especially important as drastic reductions in traffic or creative traffic solutions often will not be possible for practical, economical or political reasons. It is thus important to utilise the degrees of freedom that other strategies can offer, such as defining areas with traffic restrictions, or where building and screening can provide silence in spite of nearby traffic.

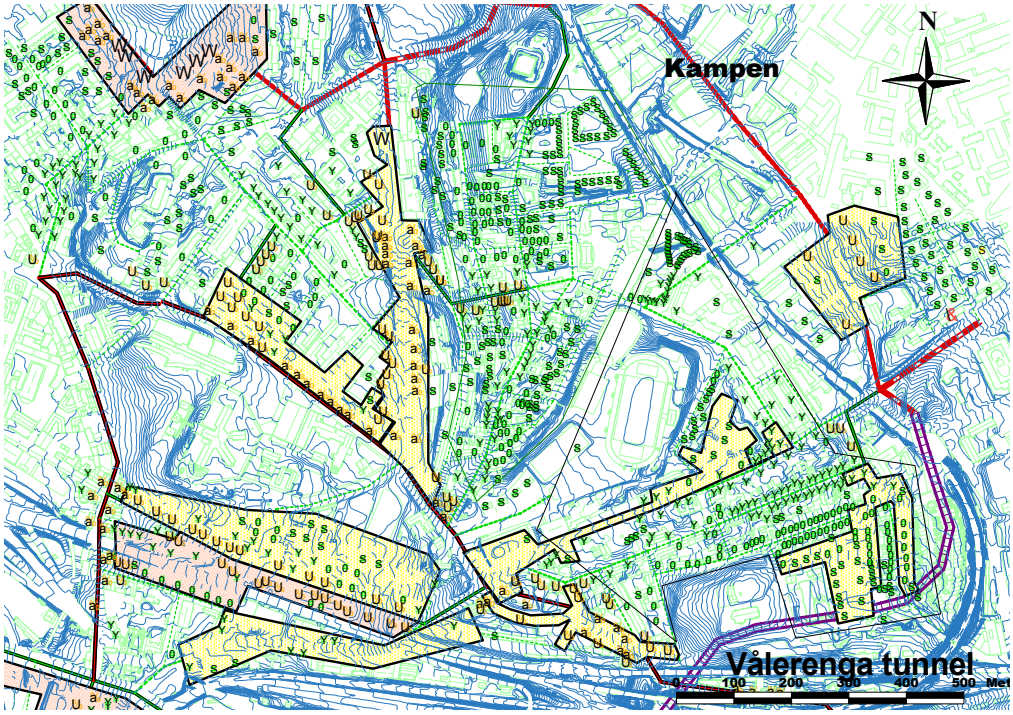

Figure 2: A map of the environmental quality of individual dwellings within a town area. The geographical algorithms will partition the areas according to the quality of adjacent dwellings. As examples Kampen and possibly Vålerenga/Upper Dalehaugen (below and to the right of Kampen) would form Environmental zones in order to improve the qualities of these areas.

It is possible also to utilise other information about the noise neighbourhood than the value of the noise exposure parameter at peoples apartment to define such neighbourhoods. Details of such an undertaking is described in (Klæboe 2000b).

2.4 Stage 3: Stratified sample of 40 Norwegian soundscapes

On the basis of the noise exposure charting of Norway and the algorithms for defining neighbourhood soundscapes, it will be possible in year 2002 to use sampling techniques to draw a stratified sample of approximately 40+ urban areas with different neighbourhood soundscape characteristics. These areas may also be representative of Norwegian urban areas by other criteria (eg vibrations, type of area, type of changes in noise exposure expected).

The stratified sample of Norwegian soundscapes can be viewed as an improved basis for making statistical inferences about noise exposure and noise annoyance in Norway as a whole. By using sampling techniques one may for instance conclude with respect to the amount of changes in noise exposure and noise annoyance in Norway as a whole irrespective of any modelling. This is the same type of inferences that it is possible to do with survey statistics of the type commonly used in monitoring political party preferences etc.

The main use of the stratified sample will however be as an improved platform for model-based statistics that may at the next step be applied to the noise exposure/noise neigbourhood data established in Stage 1 and Stage 2.

2.5 Stage 4: Socio-acoustic survey in these 40+ noise neighbourhoods

A socio-acoustic study combines a survey of the population with acoustic indicators of the noise exposure at the dwelling. As the sample of noise neighbourhoods are representative of Norway, it should be possible to obtain national annoyance and exposure figures by extrapolating the results from the areas using sampling statistical methods. The number of people surveyed may be in the order of 1500 to 2000 respondents.

As the 40+ areas are to be held constant, we will be able to systemise efforts into monitoring input factors such as traffic volumes, traffic composition, the actual layout of the area and the buildings etc. It will be much easier to keep track of changes in exposure and changes in annoyance, and differentiate between changes in annoyance that are motivated by changes in exposure and changes that have been brought about through changes in modifying factors.

An important benefit will be that the input data can be processed by more detailed terrain models such as those proposed by SINTEF.

2.6 Stage 5: Quality assurance of noise exposure model

For the 40+ areas it will be possible to do a more comprehensive analysis of the noise situation by means of more exact and computationally demanding software.(We are here thinking of efforts by SINTEF). This will on one hand provide a quality assurance to the Norway Statistics model, and possibly result in amendments to the routines. The comparison will also function as a sensitivity analysis tool showing which parts of the changes in the noise environment the Statistics Norway model picks up and which they don't.

The municipalities and the regional offices of the public road authorities and the railway authorities have an extensive database of emission and exposure data related to all noise exposed buildings in Norway. A feasibility study has been proposed by the Institute of Transport Economics to ascertain the quality of the data and the possibility of utilising the database to assess the effect of noise abatement measures on noise exposure along Norwegian major road and railroads. A specific task will be to find means to link the information to map coordinates of the buildings and if possible to the national noise mapping efforts proposed by Statistics Norway. This may result in locally adapted adjustment factors etc.

As a result of the more comprehensive analyses, possible modifications to the simplified algorithms used by Statistics Norway may be undertaken, adjustment factors taken into account and the model rerun. [4]

[4] Unless these results turn up to be very different from the first set of result this will only modify the analyses of the neighbourhood soundscapes and not result in a new stratification/sampling procedure.

Stage 6: Analyses on the basis of enhanced exposure data

By means of this environmental survey we seek to develop a general formula linking noise exposure and noise effects for Norway, so that one is not forced to develop separate exposure-response curves for each different town area in Norway.

This national exposure response curve provides one formula, but the slope and regression coefficients are made dependent on the overall quality of the urban area. A hierarchic multi level structural equation model will be built and estimated featuring area type variables at the top level and noise level + individual modifying factors at lower levels. This is somewhat analogous to the approach taken by Miedema and Vos (1999), but instead of having a random slope component it is possible to predict the size of it in terms of characteristics of the urban area.

This concludes the description of the system as it will work. The proposal however also includes innovative work in order to get a better grip on possible modifying factors. This work is meant to provide a richer understanding of the relationship between exposure and annoyance by providing control for a range of possible effect modifiers, such as environmental consciousness, size of investment in the dwelling etc.

3 Variables that may modify exposure-effect relationships

While we do not underestimate the problems of establishing a psychometrically valid measure of noise annoyance, we are in this project more interested in getting to grips with factors that may substantially alter exposure-effect relationships. In this chapter and in chapter 4, we describe a research initiative for developing measures of such possible modifying factors. This is innovative work and will have to be undertaken as a series of pilot projects in order to develop the measures further. The results of this work will be measurement instruments in the forms of questionnaire items for different types of attitudinal, individual and situational factors that may change substantially over a period of 10 years.

3.1 Motivation for looking into attitudes

After 15 years of research into the relationship between noise exposure and noise annoyance at the Institute of Transport Economics, we still do not have a firm hold of individual or situational factors influencing peoples' annoyance, nor do any one else. We are in fact back at square one – how to build measurement instruments that have desirable psychometric properties and that can help us disentangle the effects of individual and situation factors from the effects of noise exposure. Through our work with combined effects (Klæboe 2000), we have however established that there are links between people's annoyance with noise, air pollution and insecurity. Whether such links are in the form of shared sensitivities towards different environmental exposures, in the form of shared attitudes or through the fact that the individual has a finite amount of psychic energy with which to address different stressors, that may be inadequate when confronted with multiple exposure, we do not know. One thing we do know is that it is necessary to explore the different types of linkages that may exist in order to explicate the reasons for such combined effects.

With respect to attitudes, we know that there are a number of possible confounding variables that influence peoples' annoyance of noise, apart from noise exposure. In the following we will consider three different types of confounding variables: A) Attitudinal variables that may influence peoples noise annoyance directly and B) Mediating variables that are influenced by peoples' noise annoyance in period t1, generating a different level of noise annoyance in period t2, and C) Individual characteristics that modify the relationship between noise and annoyance.

3.2 Attitudinal variables that may influence noise annoyance

Although demographic variables do play a role in experienced noise annoyance, the role is for the most part rather modest. The importance of changes in such factors are even less likely to play an important role for changes in noise annoyance as the composition of the Norwegian population as a whole will not change that much over a 10 year period. While demographics are relevant, they should not be the main concern when investigating factors that influence noise annoyance. We have therefore relegated the discussion to section 3.4. Note however that Hatfield et al (1998) propose that demographic variables are more important for annoyance when assessing the effect of noise changes than in a steady state situation.

Attitudes may in our view have a more profound effect on noise annoyance than demographics, and more importantly, attitudinal variables are more volatile and may change rather quickly. As the primary interest is in charting the effects of changes in noise annoyance, it is the changes in other factors that is in focus and not the static part.

Attitudinal variables may be considered as factors that modify exposure-effect relationships. Conversely it may be thought that noise annoyance induces attitudes towards the authorities and increases interest in environmental issues. It is also quite easy to imagine bi-directional effects: that noise exposure at one point in time gives rise to annoyance that triggers attitudes that at a later stage increase noise annoyance (sensitising).

Attitudinal variables may also have a direct effect on annoyance. For instance, one can imagine that a very strong environmentalist attitude may give rise to higher levels of annoyance, more or less regardless of what the actual noise exposure is.

Attitudinal factors that can be expected to play a role on noise annoyance over a 10 years period are possibly:

- **Environmental views as reflected in political shifts:** The Norwegian political scene has the recent years seen a marked shift towards the right, and to parties that put a lot of emphasis on individual freedom. Such freedom means few restrictions on the use of cars, little support for public transport solutions and as little government influence as possible. It is fair to assume that this shift reflects changes in the environmental attitudes people hold and that these shifts are of a sufficient magnitude to alter exposure effect relationships.
- **Feelings towards the authorities:** Government policies towards petrol prices, public transport etc, are indications of the value that indirectly is placed on people's local environment. When suspected of misfeasance – that the authorities are not doing what it can to reduce problems, annoyance is known to increase. What is cause and what is effect is nevertheless not always clear. What does it mean that none of the people thinking the authorities have done a good job were highly annoyed ? What is the direction of causality and how can we decide on the basis of socio-acoustic surveys? To answer such questions it is necessary to look at a broader set of annoyance and attitudinal

indicators in order to break the "identity" of the cause and effect, and look at changes over time.

- **Global climate and attitudes towards traffic** While there has been a hefty political debate over the global climate changes and there is an increasing awareness of the need to live in harmony with nature, it is not clear how deeply this is felt by the population ("Why should we complain of it getting warmer in Norway") or what changes in such sentiments will have on noise annoyance. News research and news coverage of information such as a 25% reduction of the ice coverage of the North Pole, the possibility of changes in the Gulf-stream, may also change people's attitudes towards transport.
- **Insecurity associated with the source of noise emission:** It is documented that people that are afraid that "Things may fall down" or who are afraid of aeroplane crashes, people who are insecure in traffic or that are afraid of military exercises or gun fire, also are much more annoyed with noise than those who are not afraid. People who are familiar with or have use of a means of transport are not as annoyed as people who fail to see the utility of the mode of transport. Current prognoses suggest that the average increase in road traffic volume will be in the region of 15-20% in 2010. It is reasonable to assume that the expected increases in air traffic, road traffic and in certain areas train traffic, will result in an increase in annoyance irrespective of whether the noise emissions are increased or not.
- **Environmental sensitivity:** People who are noise sensitive are much more inclined to be annoyed. Little is known about the causes of noise sensitivity and the connections between noise sensitivity and general environmental sensitivity. Winneke & al (1996) have for instance shown that people who were annoyed by road traffic also were more sensitive to environmental tobacco smoke. The substantial increase in people diagnosed with asthma and allergies may indirectly affect peoples sensitivities also to other environmental effects. This is a field where there has been done little research.
- **Value of house and residential area:** In Oslo and other urban areas the average housing costs have more than doubled over the last 8 years. When families have a larger share of their savings tied up in property, they may feel more protective and fight more vigorously against degradation of the sound quality of the house or the residential area.

3.3 Intermediate variables influenced by noise annoyance

In addition to variables that modify exposure effect relationships, or are themselves the result of noise annoyance, it is possible to imagine variables that mediate the effect of noise annoyance from one period to the next. We will briefly consider two such intermediate variables below.

- **Expectations of noise changes:** It seems reasonable to assume that if knowledge of coming noise reductions gives rise to expectations about the annoyance reductions, people will generally not experience a reduction in annoyance of the same magnitude as the reduction in noise. It is even possible that if people expect noise reductions to a larger degree than what actually

occurs, people may experience more noise annoyance in period t2 than in period t1 even if the actual noise levels are reduced. Such effects may have a greater impact in the short run than in the long run, but are nevertheless important to be aware of. In particular the highly ambitious plan to reduce noise annoyance by 25% has the potential for generating a serious backlash if it becomes clear that the funds allocated for such an effort are seriously inadequate.

- **Urban dynamics:** Another problem in the study of noise exposure and noise annoyance using cross sectional studies is the self-selection of people living in a town area. It may be necessary to take into account social processes linking the traffic environment, social composition of the area etc to the movements of people in and out of areas with noise (Bjørnskau 1999). One may assume that an increase in noise from period t1 to period t2 will lead to movements out of the area of those who are most sensitive to noise, while a decrease makes it more attractive to noise sensitive. Such an adaptation to the noise changes will, when not taken into account, result in the underestimation of the effect of noise exposure changes on annoyance.

It is also possible to imagine that changes in the population because of changes in noise, represents an initial input to a following socially driven process resulting in larger changes in the social composition of the people living in an area than the actual changes in traffic would indicate. A mechanism behind such a development may be that the attractiveness and willingness to invest in an area is dependent on the traffic load in the area. A change in the physical environment e.g. reduced noise emissions, may attract people with more education and/or more money willing to upgrade buildings and outdoor areas. Now the area is even more attractive; both the physical and the social environment are nice, generating even more movements into the area.

Such dynamic "tipping-processes" have been modelled by Schelling (1978) and been used to explain residential segregation in the US. So, even if the differences in noise sensitivity and noise annoyance are rather small between different groups of people, a dynamic tipping-process may create substantial shifts in the population, making it possible to have rather large changes in the populations' noise annoyance regardless of changes in noise emissions.

3.4 The importance of demographic/individual parameters

Fyhri (1999) summarises the main findings of Norwegian and international research concerning individual characteristics contributing to variations in experienced noise annoyance. The main results are:

- **Education**: People with higher education report more annoyance by a specific level of noise emission than do people with lower education.
- **Gender**: Some studies find that women are more annoyed by noise than men are (Fields 1993; Hjorthol & al 1990; Kjellberg & al 1996; Kolbenstvedt, Klæboe, and Kjørstad 1990a). No studies find the opposite.

- **Children**: Parents report more annoyance with noise than do adults without children
- **Age**: Some studies find a positive association between age and noise annoyance (Klæboe and Kolbenstvedt 1995; Kolbenstvedt, Klæboe, and Kjørstad 1990b)), some don't (Fields 1993; van Kamp 1990). Some studies report a higher degree of self reported noise sensitivity among elderly (Matsumura and Rylander 1991; Stansfeld & al 1985).
- **Employment**: People who work outside their homes are less annoyed by noise than those who are at home.

Such individual characteristics may have a simple, direct influence on experienced noise annoyance of a given noise level, but they may also influence the relationship in more complex ways. For instance, Fyhri and Klæboe (Fyhri and Klæboe 1998) found that people who are employed and who are annoyed by noise at work are more annoyed by noise at home, than those who are not annoyed by noise at work.

Another example concerns children. The fact that people with children are more annoyed by noise than those without children may be explained by the fact that traffic noise comes in addition to other sources of noise that children produce, making the home a rather noisy environment. An alternative and perhaps more likely explanation is that parents are more annoyed because they are concerned about all negative impacts of road traffic on their childrens health and living conditions (accidents or sickness related to pollution). The mechanism may be that it is the total impact of road traffic that one is concerned about and not in particular noise. To express a concern for noise may be a means of expressing a general annoyance of road traffic.

Also the effect of education may be explained by various mechanisms. Higher education may give deeper understanding of environmental issues and more concern with increasing road traffic. People with higher education may also have higher standards and be more likely to complain that they are annoyed. This may more than counteract the reduction in annoyance one would ordinary assume is associated with better household economy, and improved means of protecting oneself from the adverse effects of noise exposure. Higher educated people may also more often experience concentration problems and communication problems on account of traffic noise.

3.5 Perception of noise abatement measures and changes in noise exposure

The purpose of the current project is to establish an instrument (survey) that can regularly chart peoples' noise annoyance. As mentioned in chapter 2, there are many possible factors influencing this, apart form differences in noise exposure. One might, nevertheless, consider changes in actual noise exposure levels as the most important factor contributing to changes in noise annoyance.

It is important to establish as a fact whether or not people are aware of noise abatement measures. One may expect that the implementation of such measures

might give a feeling of satisfaction regardless of whether or not the measures actually work. The point is simply that people might get less annoyed just because something has been done. It is therefore important to assess people's reactions to changes in the noise environment before enquiring into their opinions about noise abatement measures.

If we are able to get information on noise exposure, the possible modifying variables listed in this chapter, information on people's knowledge of noise abatement measures as well as data on noise annoyance, we will be able to estimate the partial more causal influences of the different factors on noise annoyance.

This will in turn make it possible not only to establish a system that regularly charts levels of noise annoyance, but also to identify significant factors bringing about the changes in annoyance. One important question when addressing the efficacy of the authorities' noise abatement programme, is of course whether or not changes in noise annoyance in the future may be attributed to actual changes in noise emissions, exposure or to attitudinal or other modifying factors.

4 Development and testing of measurement instruments

In order to summarise the possible influence the three different kind of variables may have on noise annoyance, we have outlined the possible influences in the form of a simple model, depicted in figure 3.

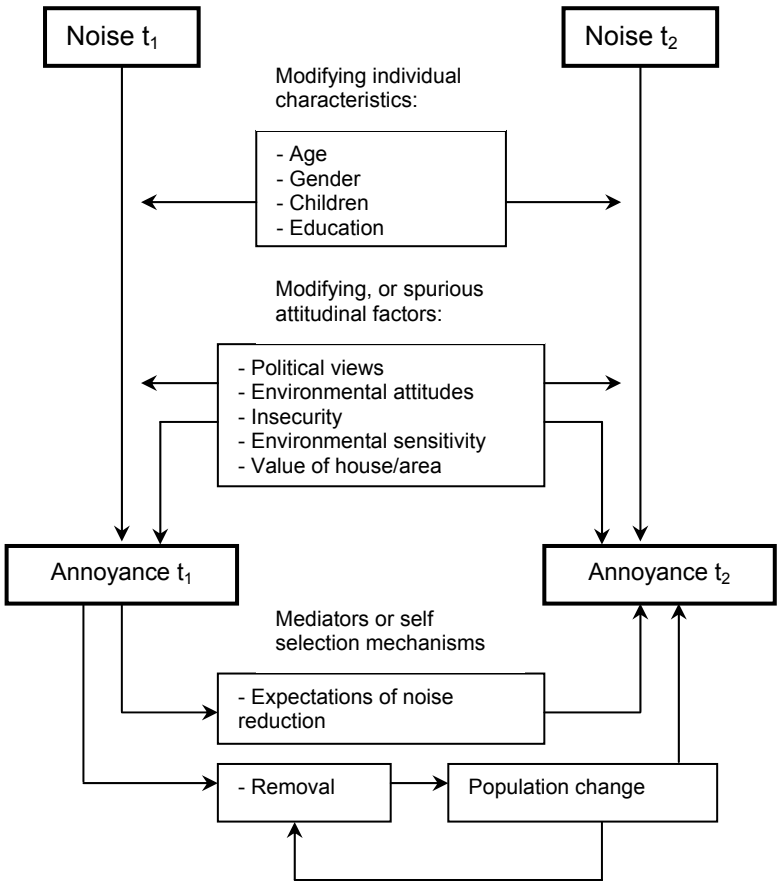

Figure 3: A model of factors associated with changes in noise annoyance.

In the model, individual characteristics are modelled so as to influence noise annoyance by way of interaction. Attitudinal variables are seen to influence noise annoyance both directly and through interaction with noise. A mediating variable is drawn in the model (expectations concerning the size of the noise changes), and also the indirect effect of noise annoyance in period t1 resulting in the self-selection of inhabitants in a town area in period t2.

It is an empirical question whether the depicted variables influence noise annoyance the way the model presupposes. But regardless of whether modifying variables are themselves the active agents or are indicators of other spurious, confounding or interacting associations, the fact remains that one may expect that different people may express quite different annoyance from the same level of noise. One may also expect that the same people may express quite different annoyance from the same level of noise at different periods of time.

Even though the model simplifies matters, it nevertheless illustrates that the relationship between noise and noise annoyance is not straight forward, especially not when one introduces a dynamic element.

In order to chart such relationships and being able to determine their relationships with each other and with noise annoyance, it is necessary to be able to measure the different attitudes and factors in a meaningful manner. In order to be able to identify which of different possible interpretations (see eg education), one can attach to a variable, it is proposed that the concepts are measured by means of indexes or by sets of variables (measurement instruments) that are derived by means of psycho-metric methods.

4.1 Methodology and practical procedures for developing measurement instruments

We will here briefly describe the method for developing the measurement instruments. How the indicators will be used, and how they will be brought into the different models explicating the relationships between different types of variables, will not be discussed here.

4.2 Adaptation and reanalyses of previously developed questionnaires

As far as possible we will try to reuse results and indicators developed by other projects. For environmental awareness there are a number of studies separating different forms of environmental consciousness and distinguishing between different types of acts (for example NSD 1993, Hellevik 1996). We will utilise results from such analyses and also perform reanalyses in order to assess the suitability of the questions for a measurement instrument with respect to noise annoyance. If there are data in the form of time series, the changes in peoples attitudes over time as measured by these instruments, will be discussed in order to ascertain the size of such changes and whether they are substantial enough to warrant their inclusion in the questionnaire of the socio-acoustic studies.

4.3 Use of focus groups to further develop measurement content

Focus groups will be used in the initial stages of establishing measurement instruments where there has been little previous research. The use of focus groups is often a convenient and rapid way of collecting data on people's perceptions of

products, brands or services - or peoples use of concepts and terms. An experienced moderator organises the group discussions in order to explore people's experience with different types of attitudes. Each discussion run through different phases where one in the first phase are more fully exploratory and in the latter phase explore more systematically themes that have been defined by the researcher.

We propose to use such groups in order to cover the different types of attitudes that people hold and explore whether there are ways of thinking about noise and annoyance that have not been captured by our short list in chapter 3.

4.4 Exploratory Factor analysis to determine dimensions

On the basis of a comprehensive set of questions it is necessary to pick the questions that map peoples attitudes most exactly and most efficiently. Exploratory factor analysis will be used in order to determine the approximate number of factors that are necessary to describe the different sets of attitudes. This will be done by means of a postal survey featuring 200 respondents.

4.5 Confirmatory Factor analysis to refine solutions

On the basis of the results of the exploratory analysis a refined set of questions representative of each of the attitudinal factors will be tested by means of an additional sample of 200 respondents. This will ensure the consistency of the instrument and guard somewhat against the capitalisation of chance that is always present when instruments are evaluated in the same process they are generated.

As a result of the confirmatory factor analysis, the result is hopefully a set of measurement instruments by which it will be possible to analyse changes in attitudes, and the impact of these changes, on changes in annoyance over time.

5 A research platform for the future

It is important to realise that the system for charting noise exposure/noise annoyance proposed by Statistics Norway and the Institute of Transport Economics is unique in that the provision of time series data with successive noise exposure and annoyance mapping, together with the access to person information at each of the buildings, will provide a means of addressing changes in noise exposure over time not only for areas but also for people. This means that the noise history may in the future be linked to health indicators.

The provision of this system will change the way local environmental surveys are undertaken in the future, and significantly reduce the amount of money spent on simply obtaining a noise map of the study areas. Noise research will be able to build upon the national platform, and the results will also be interpretable in a national framework.

Linkages to information about workplaces etc will in the future also give an improved individual noise dose estimate, and explore the impacts of having both a noisy environment at home and at work.

5.1 Soundscape mapping as a future platform for environscape mapping

A nice follow up of the work Statistics Norway and the Institute of Transport Economics to provide national indicators for noise exposure, is to add on other environmental qualities.

While we do not propose this type of work within the noise research program, it is work that if undertaken by other parties, will enhance the work already undertaken.

In particular it would be nice to provide a separate indicator of road traffic volume, speed etc as producing insecurity. Current prognosis is that traffic will increase about 18% until 2010. The added insecurity may result in people getting more annoyed at a given noise level, than if the number of cars and trucks were held constant.

Such a broadening of Soundscape modelling will provide an added impact to the exploration of local win-win situations and how multiple exposures can be dealt with effectively in an urban context.

5.2 Future differentiation of EU-legislation

An important aspect of differentiating the environmental requirements for different urban areas, and imposing local restrictions on types of vehicles, tyre

types etc., is that such regulations easily come into conflict with the four "freedoms" of EU. In the environmental zone of Gothenburg it was thus necessary to exempt long distance trucks from the requirements of retrofitting particle filters.

Figure 4: Proposed Environmental zone for Drammen, with specific requirements for the cleaning of exhaust particles. Such requirements can easily come into conflict with the freedom of competition. (Illustration from the Environmental Handbook).

At the same time it seems that such differentiation is the only viable solution for local solutions to preserving sound- and environscape quality. If future EU-legislation provides for a differentiation of urban areas, it may be necessary to define them in a way that can be acceptable to all involved parties.

If instead of local administrative boundaries, the respective city authorities could use GIS-based or GIS-aided routines in order to substantiate the rationale for the boundaries of the zone, this may provide a uniform and unbiased way of defining sensitive zones that may be acceptable and enable such differentiation to be implemented as a general policy.

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