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Towards a National Indicator for Noise Exposure and Annoyance

Part I: Building a Model for Traffic Noise Emissions and Exposure

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Part I: Building a Model for Traffic Noise Emissions and Exposure

Abstracts:
A national target to reduce noise annoyance by 25 per cent within the period 1999-2010 was stated in the Parliamentary White Paper no 8. This pilot project proposes a national noise exposure model to monitor the noise reduction target. A comprehensive, but cost-effective, GIS model of exposure to traffic noise based on data and calculation procedures from existing sector noise models of emissions and propagation is proposed. Statistics Norway's data registers on buildings, addresses and population are integrated in the model to produce noise exposure values for the single residents. The model is open-ended so that other sources of noise, e.g. industry and construction works, can be included in the future.

Keywords: traffic noise, noise exposure model

Preface:
Statistics Norway (SN) has long experience in development of integrated models and in trend measurements. SN's aim with this project has been to propose a basic framework in which existing data source and noise models can be utilised and integrated, and in which more specialised knowledge provided by other institutions can be included. This report should therefor be regarded as a description of principles to ensure integration, comprehensiveness and trend detection, rather than as a detailed an accurate description of the model's different components, including acoustic calculation procedures. This will have to be addressed in more detail during the main project period.

We thank *The Research Council of Norway* for funding. We would also like to thank *Ronny Klæboe* and Torkel Bjørnskau at the Institute of Transport Economics (TØI), and several other noise experts, for their information and support during the project.

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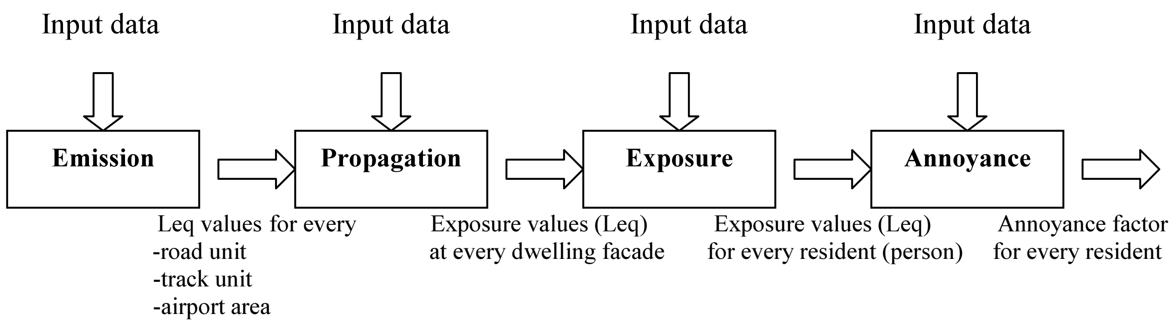
1 Summary

Approximately 1.5 million Norwegians live in areas exposed to noise (Parliamentary White Paper no 8 1999-2000). Out of these, about two thirds are exposed to noise from traffic sources (Statistics Norway 1998, Jernbaneverket 1999b), making traffic noise the most significant contributing factor to noise annoyance in Norway. Based on these facts, a national target to reduce noise annoyance by 25 per cent within the period 1999-2010 was stated in the Parliamentary White Paper no 8.

This publication documents a pilot project proposing a national noise exposure model to monitor the noise reduction target. A comprehensive model of exposure to traffic noise based on data and calculation procedures from existing sector noise models is proposed. The model is open-ended so that other sources of noise, e.g. industry and construction works, can be included in the future. The model will also serve as a basis for cognitive annoyance studies as outlined by TØI (2000).

The model is developed within a Geographical Information System (GIS) framework. It is set up as a chain-model, where noise emission, propagation, exposure and annoyance are calculated stepwise for each source of noise (road traffic, railway traffic and air traffic). Road traffic is further divided into sub-modules, according to different type of roads (international, national and provincial). The noise calculations are based on the existing sector noise models for road traffic (VSTØY), railway traffic (The Nordic prediction model) and air traffic (NORTIM).

Figure 1. A simplified conceptualisation of the model structure



The noise contour maps of airport areas produced by the NORTIM model, will be used directly as a GIS layer in the proposed model. The contour maps represent noise emission and propagation from air traffic sources, and the number of people exposed and annoyed by air traffic noise will be identified by counting the number of dwellings within the different contours.

Emission from road and railway sources will be calculated from activity data from the Official Road Database (Vbase) and the Railway Data Bank (Banedatabanken), and by use of calculation procedures from the existing sector noise models (VSTØY and The Nordic Prediction Model for Railway Traffic). The road/track units are the main parameters in Vbase and Banedatabanken. Thus, emission values will be attributed to every unit.

Propagation will be calculated by identifying noise modifying factors, i.e. distance, screens, and interjacent buildings, between the emission units and the dwellings exposed to traffic noise. The dwellings can be identified from geo-references in the official register for Ground properties, Addresses and Buildings (GAB). Within the GIS framework, a line can be constructed between the dwellings and the emission units from which they receive noise. This line is used as a reference for identifying the noise reducing factors between the emission units and the particular dwelling.

Exposure values can, thus, be attributed to every single dwelling affected by noise. The number of residents connected to every address can be identified by linking information from the GAB with information from the Central Population Register (CPR), thus a noise exposure value can be attributed to every resident of the dwellings.

Annoyance values can be attributed to the single residents by use of a Noise Annoyance Index (SPI), which converts the noise exposure values to annoyance expressions.

The national goal is stated as percentage reduction in annoyance. The model concept is consequently designed to ensure comparability between years rather than to detect the exact number of people exposed at a single year. Emphasis will be put on including parameters that have effect on trend rather than level. This will also ensure that the model is kept as simple as possible. This is mandatory in order to make it a practical tool for monitoring and to ensure operationality and cost-effectiveness. Improved knowledge and data quality will, however, be taken into account when it becomes available, and the model may be re-calculated every year on the basis of this information.

Data for sophistication and extensions of the model will basically have to come from external sources, i.e. from specialised studies on noise emission and propagation performed by institutions like SINTEF. There are, however, also new projects carried out by Statistics Norway, which open new opportunities for improvements of the "population variable". Of particular interest are projects that link information from the GAB, the CPR and the Central Register of Establishments and Enterprises (BOF). The results from these projects will make it possible to identify people's actual location through the day. The Population and Housing Census planned for 2001 will also provide new information that can be used for the same purpose.

The main conclusion from this pilot project is that a noise monitoring model, as proposed, can be operative by 2001 based on already existing data sources and data processing capacity. A pre-condition, however, is that processed data from VSTØY and other national traffic models are made available as input to the model. It will be possible to produce figures for 1990 (simplified) and 1999 by the first year of operation. Thereafter, new figures can be produced annually, with the possibility to re-calculate the whole time series at the same time.

2 Introduction

This report presents a proposal for a model to map and monitor the number of people exposed to traffic noise in Norway. A separate report from this joint pilot project between Statistics Norway (SN) and the Institute of Transport Economics (TØI) describes a system for connecting the output data from the exposure model to community survey data on noise annoyance to be able to map changes in noise annoyance (TØI 2000). The project is part of a research programme dedicated to noise research funded by the Research Council of Norway. The programme goes into its main phase in 2001. The intention of this report is to propose a practical and cost-efficient system of noise monitoring which can be implemented and operational from 2001.

2.1 Background

According to the Parliamentary White Paper no 8 (1999-2000) to the Storting 1.5 million people in Norway are exposed to noise *outside* their residences. Statistics Norway's *Survey of living conditions* (Statistics Norway 1998) indicates that 700 000 people in Norway were exposed to road traffic noise *inside* their residences that year. Nearly half of these found the noise annoying or severely annoying. About 176 000 of the people exposed to noise from air traffic found the noise annoying or severely annoying. The survey also indicates that 5 per cent of the population experience sleep problems as a result of noise. According to a survey conducted in 1999, about 76 000 people were exposed to noise from railway traffic in Norway, of which 16 300 were severely annoyed (Jernbaneverket 1999b).

Last year the Norwegian Government presented an integrated statement on its environmental policy jointly with the state of the environment report. In this report national targets for different environmental issues were presented. The national target concerning noise is 25 per cent reduction of noise annoyance within the period 1999-2010 (The Parliamentary White Paper no 8 1999-2000). The national target covers all noise emitting sources.

2.2 Objectives

The main objective of this pilot study has been to assess the possibilities to develop a national model to monitor the number of people exposed to and annoyed by traffic noise in Norway, and to outline a model proposal based on this assessment. According to the application for a main project for 2001 we propose that the first version of the model should concentrate on noise from road, railway and air traffic. In later versions of the model further noise emitting sources, such as trams, industry, harbour activity, construction and shooting ranges, may be included and the entire time series for exposure and annoyance may therefore be recalculated when needed.

The proposed model is developed as framework to combine the best parts of the existing sector models like VSTØY and NORTIM with data from the Central Population Register (CPR), the official register for Ground properties, Addresses and Buildings (GAB) and the Population and Housing Census for 2001. Thus, the main purpose of the model is to integrate existing models, calculation procedures and data sources into a comprehensive framework which can produce joint exposure values for the different sources of noise at a national scale as well as monitor the annual changes in noise exposure.

In the search for a national indicator model of traffic noise exposure and annoyance the following premises were emphasised:

- *It should focus on reflecting the annual change in noise exposure rather than being pre-occupied with finding the precise baseline figures*
- *It should prioritise inclusion of parameters related to changes in noise exposure in order to be able to monitor effects of noise policies and measures*
- *It should make use of existing data to ensure an early start of operation and to be cost-effective*
- *It should be kept as rational as possible to ensure minimisation of data processing requirements and cost-effective operation*

- *It should be open-ended and flexible, in the way that it should enable sophistication and extensions based on improvements in the knowledge base and data quality*

Since the national target is given as a trend change (25 per cent reduction of the annoyance) it has been important to develop a model that measures real annual changes in noise exposure and not changes in methodology. The model must take into account the most important noise reducing measures. Since we are studying the trend, it is possible to make some simplifications concerning parameters that can be particularly important for the noise level locally, but not as important for the national trend (for instance type of ground, angle of view etc.). To promote cost-efficiency, we suggest developing a result control system based on calculations of exposure and annoyance instead of direct surveys concerning annoyance. The model will, however, be designed to serve as a basis for more in-depth annoyance studies as proposed by TØI in the second report from this project (TØI 2000).

This pilot project has included the following activities of which the model proposal has been based:

1. A review of existing models on noise exposure, both national and international, in order to generate ideas and to learn from experiences
2. An identification of the relevant parameters required to develop and operate a noise exposure model
3. An identification and assessment of the available data sources covering the relevant parameters
4. An assessment of the prospects for further development of the model, and the possibilities of fulfilling the proposed EU requirements on noise reporting

2.3 Measuring noise exposure and annoyance

2.3.1 Noise measurement scales

Sound (and noise) is measured in decibel (dB), which is a logarithmic unit expressing the ratio of the sound pressure level being measured to a standard reference level. Sound is composed of various frequencies, but the human ear does not respond to all frequencies. Thus, frequencies to which the human ear does not respond are normally filtered out when measuring noise levels. The filter which best approximates the frequency response of the human ear is referred to as the A-scale, or A-weighted dB (dBA). All dB values in this report refer to dBA.

Noise, defined as "unwanted sound", will be perceived differently by different people. First of all, there can be disagreements about what sounds that should be defined as "noise". But more important, when it comes to measurements of noise are the volume, frequency, duration, and the time of occurrence of the sound events. All of these factors are relevant for people's perception of noise, but their relative importance may differ from case to case. Thus, different scales of measurements, which emphasise on different factors, are used to express noise. The scales used in this report are described below.

1. The maximum sound pressure level (Lmax)

Lmax is a measure on the highest sound levels during a defined period of time, e.g. 24 hours. The measure should not include accidental, or unrepresentative, sound events during the period.

2. The equivalent continuous sound pressure level (the time average level) (Leq)

Leq is the most commonly used measure of noise related to traffic sources. Leq can be described as the level of the total sound energy (the total noise dose) which, over the same interval of time as the fluctuating sound of interest, has the same mean square sound pressure.

3. Weighted equivalent sound pressure levels (EFN)

EFN is used in the Norwegian air traffic noise calculations, and can be described as a sophisticated version of the 24 hour Leq. The 24 hours period is divided in a day and a night period, where a sound event during the night period (00.00 - 06.00) is weighted ten times (10 dB) an event during the day (08.00 - 18.00). The periods between 06.00 - 08.00 and 18.00 - 00.00 are transition periods where the weighting factors decrease/increase gradually between the night (10) and day (1) factors.

4. The proposed EC standards (Leu, Leu,n)

The EU Working group on indicators recommends two different indicators for reporting noise exposure in the EU member states. The Leu is based on the same concept as the the EFN, but the 24 hour period is divided in a 12 hour day period, a 4 hour evening period, and a 8 hour night period, where the weightings ("penalties") are 5 dB for sound events during the evening period, and 10 dB for events during the night period. The Leu,n is the Leq for the 8 hour night period without any weighting.

5. Cumulative noise factors

When a building or a person is exposed to two sources of noise, i.e. from two different roads, the total, or cumulative, sound level has to be calculated according to the table below. If there are more than two sources involved, the two lowest contributing sources are summarised as described. This new sound level is then summarised with the third contributing source following the same procedure.

Table 1. Accumulation of multiple sources of noise

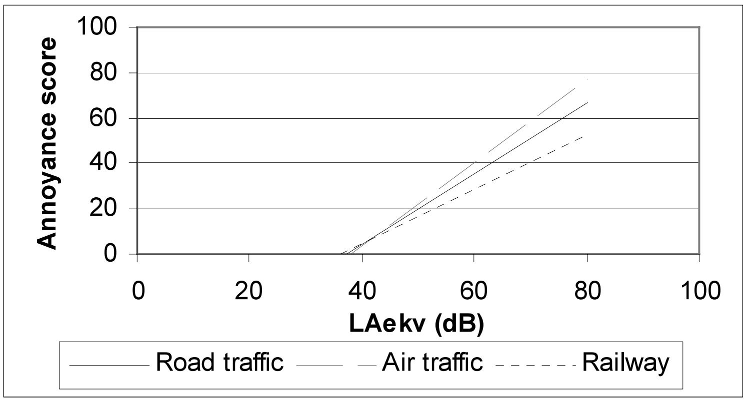
Difference in dB(A) between two sources of noise	0-1	2-3	4-9	>9
Addition (dB(A)) to highest contributing source	3	2	1	0

6. The Noise Annoyance Index (SPI)

The national target on noise reduction refers to a reduction in *annoyance*. Thus, it is necessary to convert the exposure dB values to a noise annoyance scale of measurement. As already mentioned, annoyance includes a cognitive dimension, which makes it more difficult to quantify than exposure. Studies have, for example, revealed that people accept higher sound levels from railways than from road traffic, without expressing that they feel more annoyed from the former (see figure 2). This can partly be explained by the limitations of the noise measurement scales, which do not reflect the periods of total silence between the train passings, and partly by a general higher public acceptance of the railway as a source of noise.

Noise annoyance can, however, be measured directly from dB values by the use of a Noise Annoyance Index (SPI). The SPI below (figure 2) is developed on basis of range of studies in the European countries, which have compared physically measured dB noise values with people's expressions of annoyance from the same traffic sources. The annoyance studies proposed in part 2 of this project (TØI 2000) may lead to a specific SPI index for Norway.

Figure 2. The Noise Annoyance Index for traffic sources (Miedema 1998)



Source: SFT (2000)

2.3.2 Recommended maximum noise exposure levels

As already mentioned, dB are expressed on a logarithmic scale, and the following effects in relation to exposure levels may serve as a guideline to make the scale tangible:

0 dB = lowest audible sound
120 dB = the limit of pain
150 dB = instantly and permanent pain and loss of hearing

The recommended maximum levels of exposure to traffic noise in Norway are at present based on the recommendations from The World Health Organisation (WHO) (see table 2) (Berglund & Lindvall 1995). These limit values refers to the Lmax and Leq measurement scales. When the proposed EU directive comes into force, it will contain new recommended maximum values expressed in dBeu and dBeu,n. These will also become valid for Norway.

Table 2. Recommended maximum noise exposure levels for road and railway traffic in Norway

	Leq	**Lmax**
Indoor environments		
measured outside facades		
- residences	55-60	70-80
- health institutions	50-55	65-70
- schools, kindergartens	55-50	
measured indoors (with closed windows)		
- residences	30-35	45-55
- health institutions	25-35	40-45
- schools, kindergartens	30-35	
- places of work	40-45	
Outdoor environments		
- residential areas	55-60	
- health institutions	50-55	
- schools, kindergartens	50-55	
- built-up recreational areas	50-55	

Source: Miljøverndepartementets rundskriv t-8/79

3 A review of existing noise models

There already exist noise measurement systems for all the traffic sectors covered by the proposed model in chapter 4. However, these sector models are not developed to provide a regularly and comprehensive picture of the noise situation on a national scale. The national sector models are briefly described in this chapter. Included in the review is also a description of two Dutch models, which are developed with same objectives as in this pilot project.

3.1 Road traffic

3.1.1 VSTØY

The Norwegian Directorate of Public Roads has developed the model VSTØY to calculate the noise level and annoyance on road sections. The model is based on the simplified version of the Nordic Prediction Method for Road Traffic Noise (see Chapter 3.1.3). It has been developed special models for more detailed calculations (The Norwegian Directorate of Public Roads 1999). These models are based on the complete version of the Nordic Prediction Method.

Some of the data from VSTØY are also found in Vegdatabanken. Among important parameters in the model are:

- Traffic flow (ÅDT - average number of cars per 24 hours on a road section)
- The percentage heavy vehicles of the total traffic flow
- Speed
- Road gradient (This parameter gives the road gradient in per cent.)
- Height of buildings
- Screens (2 types: 5-10 dBA and >10 dBA)
- Distance (from the road to the receiver)
- Ground (soft/hard)
- Angle of view
- Type of building

The speed data that is included in the VSTØY model is real speed (average measured speed). Where such information is lacking speed limits is used. In the VSTØY model speeds less than 10 km/h are set to 10 km/h while speeds larger than 90 km/h are set to 90 km/h.

3.1.2 The national status study 1991

This work is based on the TP10 work (plans for transport in the 10 largest cities in Norway) and «Norsk veg- og vegtrafikkplan» (NVVP) 1994-97. The results were scaled to a national description of road traffic noise (Asplan Viak 1993). The calculations are based on data collected in these plans to the VSTØY noise prediction model for road traffic.

3.1.3 The Nordic prediction model

The first version of the Nordic prediction method for road traffic noise was published in 1978, the second version in 1989 and the third version in 1996 (Nordic Council of ministers 1996). The Norwegian Directorate of Public Roads published a revised method in Norwegian in 2000 (Statens vegvesen 2000).

The method is based on the equation:

$L_{Aekv} = L_{1ekv} + \Delta L_{2ekv} + \Delta L_{3ekv} + \Delta L_{4ekv} + \Delta L_{5ekv}$

where:

L_{Aekv}	is the A-weighted equivalent continuous *sound pressure level* in decibels (dB)
L_{1ekv}	is a value of the *basic noise level*. The input parameters are number of heavy and light vehicles and average speed.
ΔL_{2ekv}	*Distance correction*
ΔL_{3ekv}	*Ground and barrier correction*
ΔL_{4ekv}	*Other corrections*. This could be correction for influence of road surfaces, vegetation, angle of view, thick screen, road gradient etc.
ΔL_{5ekv}	*Facade sound insulation.* This is the difference between sound pressure inside and outside a building.

In the report graphs and equations helps to calculate noise levels and correction factors for each road piece.

BOX 1: Data sources for road traffic

The model **VSTØY** *will be used to calculate average functions. One problem in using the registers from the VSTØY model as input for time series of noise is that the registers have become more and more complete over the last years. A greater part of buildings and roads may be registered in for instance 1997 than in 1991. This can lead to a trend in the noise levels and noise annoyance that is not real but a result of a changing methodology. This problem will probably be less for the period 1999-2010, which is the period for the national target for noise.*

Vegdatabanken:
The Norwegian Directorate of Public Roads runs the Vegdatabanken (Road database) where data for international, national and provincial roads in Norway are stored. The data are stored for road sectors. Vegdatabanken includes data for the road sections on:

- *Average number of cars per 24 hours*
- *Percentage heavy vehicles*
- *Speed limits*
- *Screens*
- *Ground*
- *Road gradient*
- *Etc.*

The road database does not, however, contain important parameters such as:

- *Year of construction*
- *Year of extension works*

3.2 Railway traffic

3.2.1 The Nordic prediction model

The new Nordic prediction method for train noise (NMT) (Nordic Council of Ministers 1996) is used to calculate Leq, and Lmax (in octave bands or as overall A-weighted levels), for individual passing trains in the Nordic countries. The NMT has replaced the simpler and manual old Nordic prediction method. A manual prediction method is still in use, but has been updated from the old version to correspond with the NMT.

The NMT describes a procedure to calculate the noise levels obtained in a given receiver position (exposure) based on the following three main factors:

1. The source (traffic mix, wheel/rail maintenance and operating conditions)
2. The topography
3. The receiver location

The calculation procedure of the NMT is referred to as the "sound propagation method", and can be expressed as:

$$Lp = Lw + \Delta Lc + \Delta Ld + \Delta La + \Delta Lg + \Delta Ls + \Delta Lv + \Delta Lr \quad \text{dB}$$

Where
Lp = Sound level at the receiver (dBLeq or dBLmax)
Lw = The noise emission at source determined from the train type (1), speed and traffic volume (and total train length for calculation of dBLeq)
ΔLc = Correction for track conditions (2)
ΔLd = Correction for divergence (3)
ΔLa = Correction for air absorption (3)
ΔLg = Correction for ground effects and uneven terrain (3)
ΔLs = Correction for screening effects (3)
ΔLv = Correction for the effects of vegetation (3)
ΔLr = Correction for the effects of reflecting surfaces other than the ground (3)

(1) Normal sound emission values for the different train types at different speeds are established on basis of a large number of measurements in the Nordic countries
(2) ΔLc = 0 should be used for ballasted track with continuously welded rails on concrete or wooden sleepers, and maintenance procedures typical for country in question. In the Norwegian NMT calculations, maintenance is assumed as "normal" for all tracks
(3) Correction procedures and factors are given on pp. 19-27 (Nordic Council of Ministers 1996)

Approximately 50 per cent of the Norwegian railway system is covered by noise estimations according to the new NMT procedure. The uncovered 50 per cent of the system is primarily located in less or non-populated areas, where the lack of topographical maps on a micro scale (20 metres contours) is the main limiting factor for total NMT calculations.

BOX 2: Data sources for railway traffic

Banedatabanken *(the railway data bank) is the main data source for noise related data on railway traffic. The databank contains information on parameters related to both the track units (such as screenings, land cover, topography, bridges, tunnels, etc.) and the trains (noise emission factors for passenger and freight trains, traffic flow, etc). Data on traffic flow and train types can also be collected from ordinary* **time schedules**.

3.3 Air traffic

3.3.1 NORTIM

NORTIM is a Norwegian developed computer program for estimating noise from air traffic (Olsen et.al. 1995). The program is based on the American Integrated Noise Model (INM), but, in addition, it takes into consideration the effects of the topography, and sound reflecting surfaces, on the sound propagation. The program can also be used to calculate noise on different scales, i.e. EFN, MFN and Leq (SINTEF 2000).

NORTIM contains a "noise database", which is primarily a copy of the INM database, of 107 different types of aircraft. The database makes up the basis of the noise calculations together with traffic mix, flight tracks and topographical information. Traffic mix is estimated between 1. May and 30. September, which is the period associated with the most serious noise problems. Military training flights during exercises are included in the traffic mix if they are carried out as often as every second year.

The results from the NORTIM calculations are presented as noise contours for every 5 dB from 50 dB. The contours can be processed in any scale, and they can be exported in normal GIS formats (DXF or SOSI formats).

Up to today noise results for 10 Norwegian airports have been produced by the use of NORTIM, and another 5 airports will be covered this year. However, noise contour maps for all other civilian and military airports have been produced in connection with a national investigation of people exposed to traffic noise in 1999.

Since 1997, a programme has been carried out to improve NORTIM further, with regards to quality assessment, calculation effectiveness and results accuracy. The improvements are scheduled to be operative within the end of this year (www.luftfartsverket.no/miljø).

The NORTIM results are reassessed every fourth year, and revised every eighth year.

Box 3: Data sources for air traffic

The **NORTIM database (the Civil Aviation Authority)** contains information on:
- types of aircraft (noise emission factors)
- traffic flow
- flight tracks
- topographic data
- wind directions
- noise reduction structures

The most dynamic of these data, i.e. traffic flow and types of aircraft, can also be collected from ordinary **time schedules**

3.4 Integrated models

3.4.1 The EMPAA model
The Environmental Model for People Annoyance Analysis (EMPAA) (Dassen 2000, Dassen and Jabben 1999, RIVM 1999) is developed and used to calculate and analyse the extent of annoyance (due to local environmental problems) on a national scale. From inquiries it is known that noise, local air pollution, odour and external risks are the main topics which cause annoyance (and concern).

The model is developed within a Geographical Information System. The GIS communicates with a MATLAB-module. This module takes care of the calculation of the transmission (from sources to reception points). The whole system is set-up as a 'chain model', of which emission, transmission, exposure and effects are calculated stepwise. Furthermore, the model enables to check with policy aims and has the functionality to study the effects of measures.

In the pre-processing part, the GIS is used to calculate the spatial distribution of the emission, to combine this information with spatial data of the environment, and to get the data sets in the format needed for the transmission model. The result of the transmission model is a grid with a value for the (noise) load appointed to every 100x100 m cell of the grid. The post-processing part of the GIS is used to make up the maps, to calculate the exposure and annoyance, and to express exposure and annoyance in indicators (e.g. number of people exposed to 65 dB or more, or number of people (seriously) annoyed).

At this moment, EMPAA is operational for road traffic noise (with sub-modules for highways, provincial roads and local roads), railway noise (all tracks) and airport noise (all (civil and military) airports and airfields). The model is still under development for noise from industry, local air pollution and odour. External risk contours are calculated in another model. It is currently investigated whether these can be included in the EMPAA system. For this, it is now investigated whether the same input data can be used. Furthermore, it requires further tuning of the presentation of risk and noise contours and the analyses done with them (Dassen 2000).

3.4.2 URBIS

URBIS (Instrument for Local Environmental Surveys) is another Dutch model, developed for calculation of spatial distribution of air pollution and noise and the associated health risks for (parts of) municipalities. The model describes the current and possible future states by means of maps and indicators of the environmental quality and risks. It also produces overviews of sources and their relative contributions (TNO 2000).

A fundamental principle of the URBIS model is to make use of already existing data, which for a large part is provided by the municipalities. On basis of activity data (traffic density, velocity, etc.), URBIS calculates *emissions* in separate emission models. For some sources, emission data are directly available. Environmental quality in terms of noise levels is calculated in *transmission* models. In doing so, environmental data like ground surface type and buildings configurations are used in addition to emissions. In some cases, directly available information on environmental quality is used, i.e. noise contours for air traffic.

Exposures of dwellings and inhabitants are estimated by combining the micro-scale calculated environmental quality with information about the buildings and the numbers of inhabitants. The estimation of the actual exposure to noise can be improved by using available information on noise reduction measures and on orientation of the buildings. Next, the calculated exposure can be combined with exposure/response relations to estimate risks, for example the risk of serious noise annoyance. These estimates can be combined into for example the anticipated number of people experiencing serious annoyance by noise or the anticipated life span reduction.

Finally, the results are processed and presented in maps, tables and indicators. These results will also become available in files to enable further external processing, for example by municipalities in their own geographical system. URBIS uses receptor points at every 10 metres in the immediate vicinity of the source and regular grids with points at every other 25 metres for the rest of the area. Consequently, the results are suitable to draw up high-resolution maps of the municipal environment. Although URBIS calculates noise exposure on relatively detailed scale, the model's main principles and methodological approaches may well be converted to a more general scale.

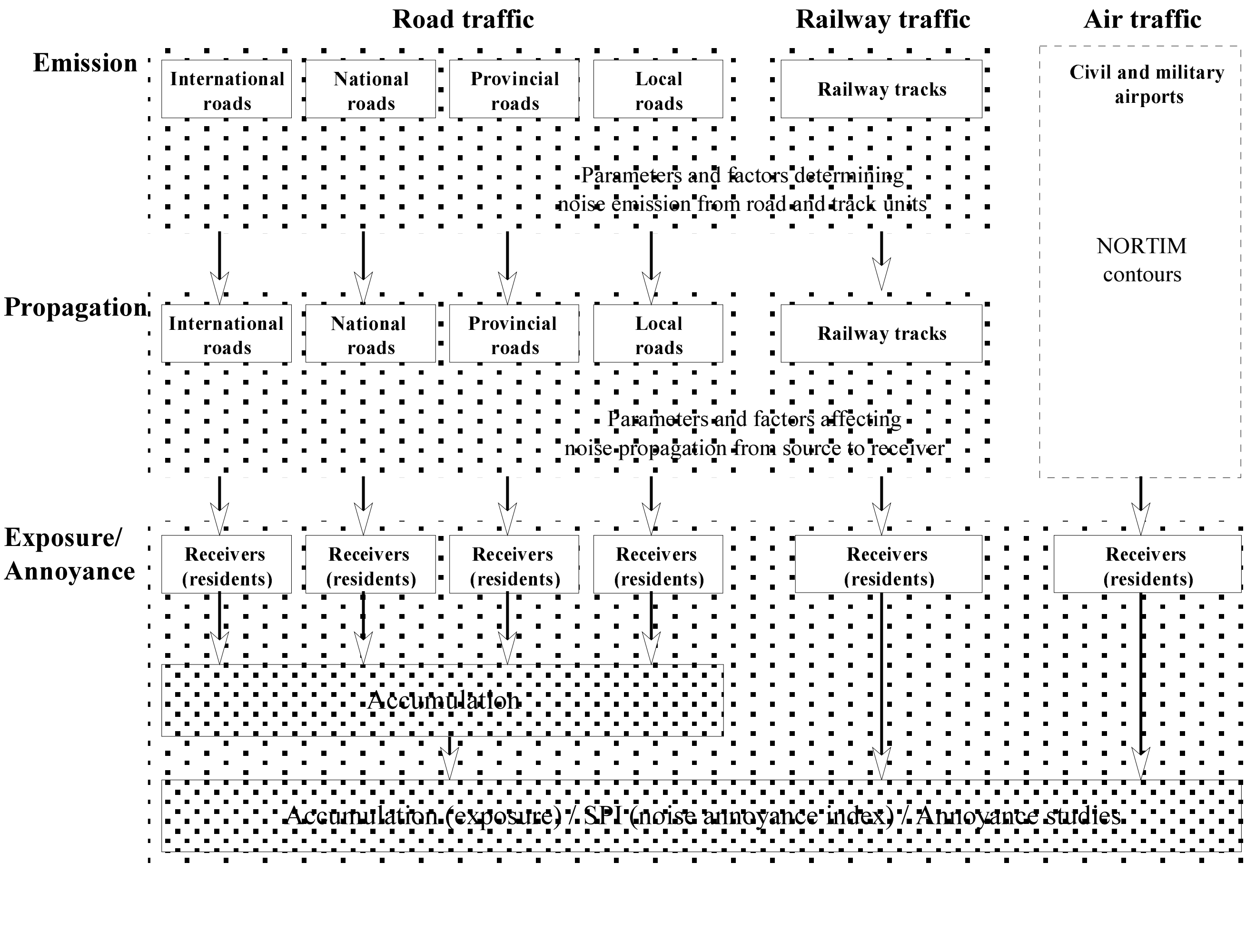
4 The model proposal

The model proposal presented below is based on the utilisation of already existing data sources, and the other basic premises outlined in chapter 2.2. The purpose is to provide an operative national indicator of noise exposure and annoyance from 2001. The model is, however, open-ended. That means that it is possible to include future improvements in knowledge, input data, and parameters. The model may also be extended to include other sources of noise.

4.1 Conceptual framework

The model is divided into different modules corresponding to the different sources of noise; road traffic, railway traffic, and air traffic. Road traffic is further divided into sub-modules according to the type of road. Calculation of noise emission, propagation, exposure, and annoyance is carried out stepwise for each of the different modules. However, the sub-modules are integrated to handle exposure to several sources of noise. For air traffic the noise contour maps from NORTIM (see section 3.3.1) are used directly to state emission and propagation (updated every fourth year), leaving exposed residences and residents the only variable which will be updated annually. The modules, and the stepwise calculation procedure, are conceptualised in figure 3, and the calculation procedure is further outlined on the following pages.

Figure 3. The model framework showing the different modules and the stepwise calculation procedure



4.2 Emission

Emissions can be calculated on basis of different parameters, and factors describing their contribution to noise generation. The different sources (roads and railway tracks) are divided into units, or segments, defined on basis of the relative homogeneity of the noise generating parameters. Thus, noise emission may be calculated for each segment of road or railway track. Emissions from air traffic are treated separately in chapter 4.5.

4.2.1 Road traffic

We here propose a new model for noise emission and propagation where VSTØY and the Nordic Prediction Model is used indirectly in the calculations together with data from the Vegdatabanken. The model could in principle have been based on annual VSTØY calculations for the whole country. It is, however, mandatory that a result control system is kept relatively simple to be cost efficient. In the proposed model simplifications are justified because the national target concerning noise is stated as a percentage reduction in annoyance. This means that parameters that do not change much from one year to another, such as type of ground, angle of view, will be less important to the trend in annoyance and can be based on average values. The main application of VSTØY is calculating the noise level at a local scale. For this use the parameters listed below will of course be important.

With a model with indirect use of VSTØY the cost with annual updates and recalculations due to new knowledge will be small. SN recommends that the model should be kept as simple as possible in the first version. Later the model can be developed if sensitivity analysis concludes that other parameters are important for the trend in annoyance. SN will propose to develop an input-output database that makes recalculations back in time simple.

Relevant parameters:

Important parameters that affect the trends in noise emissions includes:

- engine technology
- tyres (for instance tyres with or without studs)
- speed
- average number of vehicles per 24 hours on each road sector (ÅDT)
- percentage heavy vehicles on each road sector
- road gradient
- road surface (incl. coverage of snow or ice)
- start and stop areas (i.e. bus pockets)

The emission model:

It has been a goal to keep the emission model simple. The model must, on the other hand, give good estimates for the annual change in the noise annoyance from 1999 to 2010. Some of the parameters in the model will be updated annually while others can be kept constant for some years or through the entire period.

We plan to utilise both data from the VSTØY model and Vegdatabanken/NORVEG in the emission model for noise from road traffic outlined below. From VSTØY different reference noise values can be calculated for a road section based on data of:

- "ÅDT"
- engine technology/age
- traffic flow for the two categories light and heavy vehicles
- speed limits if real speed (measured average speed) is not available
- road gradient
- use of studded tyres (in per cent)

Ca. 20 reference noise levels must be calculated for different traffic flow and speed.

We will make correction functions that describe how the noise level in a road sector will change if:

- "ÅDT" is changed by *X* thousand vehicles
- the part of the traffic flow is changed by *Y* per cent
- the speed limit is changed by *Z* km/h
- the road gradient is changed to *S* per cent
- the part of the vehicles using studded tyres is changed to *P* per cent
- the age of the cars are changed by *T* years

Based on the reference noise level and the correction functions the equivalent noise level for a road sector can be calculated in the model. The Norwegian Directorate of Public Roads, SINTEF or other institutions should calculate the correction functions to be used in the model. The flexible structure of the model makes it possible to make approximate estimates for these functions in the first version of the model. In later versions these functions can be revised. The most important correction functions can be improved in separate projects. The resulting information can easily be used to recalculate the entire time series of noise emissions to capture real changes.

The Norwegian Directorate of Public Roads (Vegdatabanken) may provide data on traffic flow, part of the traffic flow by heavy vehicles, speed limits and road gradients for most of the national and provincial roads. For the local roads we will use some data described in this section.

We aim to utilise results from future projects by SINTEF or other institutions. This could be projects that give information on noise as a function of age of cars, model, engine type etc.

Not all of the data in the model have to be annually updated. Some of the data can be assumed constant for some years or the whole period. Road gradient is of course an example for the last issue. Speed may have large local importance, but the importance for the national trend is assumed small.

In the first version of the model we will not take road surface into account.

The noise emission model for a road sector can be formulated:

$$L = L_{Reference} + \Delta L_{ÅDT} + \Delta L_{V} + \Delta L_{\%heavy} + \Delta L_{gradient} + \Delta L_{stud} + \Delta L_{age}$$

The parameters in the model is described below:

Equivalent noise level (L)
Calculated equivalent noise level on road sector ***n*** in dBA.

Reference noise level ($L_{Reference}$)
Reference noise level by a given "ÅDT", percentage heavy vehicles and speed limit.
$L_{Reference}$ = f(ÅDT=X, TA=Y, V=Z) for approximately 20 different combinations of X, Y and Z. Every calculation has a range of validity with respect to ÅDT, percentage heavy vehicles and speed limits. The reference values may be calculated by the use of the VSTØY model.

Correction function for traffic flow ($\Delta L_{ÅDT}$)
This is a correction function that describes how the difference between a "ÅDT" on *X* (used in the reference noise level calculation, $ÅDT_{ref}$) and the "ÅDT" on the actual road sector ($ÅDT_{X}$) affects the noise emission. The function can be expressed by the equation:

$$\Delta L_{ADT} = \Delta ÅDT * f(\Delta ÅDT)$$

where

$$\Delta ÅDT = ÅDT_{ref} - ÅDT_{X}$$

The function f(ΔÅDT) may be provided by the Norwegian Directorate of Public Roads for the different reference noise values.

The "Vegdatabanken" may provide data on traffic flow on each road sector. The "Vegdatabanken" only include data for national and provincial roads. Separate calculations must be performed to estimate traffic flow on local roads. For some road sectors the Norwegian Directorate of Public Roads does not have any measurements of traffic flow. For these sectors they have estimated the flow. The time series on road sector basis for traffic flow will be uncertain for the period 1990-1999.

Correction factor for speed (ΔL_V)
A correction function that describes how the difference between a speed (V) on *Y* km/h (used in the reference noise level calculation, V_{ref}) and given speed on the actual road sectors (V_X) affects the noise emission. The function may be expressed by the equation:

$$\Delta L_V = \Delta V * f(\Delta V)$$

where
$\Delta V = V_{ref} - V_X$

The function $f(\Delta V)$ may be provided by the The Norwegian Directorate of Public Roads for the different reference noise levels. The "Vegdatabanken" may provide data on speed limits for the sectors. Notice that this is not the same as real speed (measured average speed).

The quality of the speed data will be best for the national roads. Data from provincial roads are not of the same quality. Data from local roads are lacking. The time series will most probably not be as uncertain as for traffic flow.

Correction factor for percentage heavy vehicles ($\Delta L_{\%heavy}$)
A correction function that describes how the difference between a percentage heavy vehicles of *Z* per cent (used in the reference noise level calculation, TA_{ref}) and the given percentage on the actual road sectors (TA_X) affects the noise emission.

$$\Delta L_{TA} = \Delta TA * f(\Delta TA)$$

where
$\Delta TA = TA_{ref} - TA_X$

The function f(ΔTA) may be provided by The Norwegian Directorate of Public Roads for the different reference noise levels. Information on the percentage heavy vehicles is also included in the "Vegdatabanken" for some road sectors. For the rest of the sectors average values have to be used. The time series will be very uncertain.

Correction factor for road gradient ($\Delta L_{gradient}$)
A correction function that describes how the difference between a road gradient of 0 per cent (used in the reference noise level calculation) and given gradient on the actual road sectors affects the noise emission.

The "Vegdatabanken" may provide data of road gradients for the road sectors. Of course time series are less important for this parameter. Some road sectors are changed but this is not taken into account in the first version of the SN/TØI noise model. This may be included in the model if sensitivity analysis prove that such changes affect the time series. The quality of these data in the "Vegdatabanken" is assumed poor.

Correction factor for percentage studded tyres (ΔL_{stud})
A correction function that describes how the difference between the value of 20 percentage of the vehicles using studded tyres in the winter (used in the reference noise level calculation) and given percentage on the actual road sector affects the noise emission.

The Norwegian Directorate of Public Roads has performed surveys for the most recent winters in order to estimate the percentage of the cars, which use studded tyres (The Norwegian Directorate of Public Roads 1998). Figures are given for each county and have been updated annually in the nineties.

Correction factor for age (ΔL_{age})
A correction function that describes how noise varies with the age of the cars. This age correction function is used as an indicator for the effects changing engine technology has on noise emission.

The Central Register of Vehicles may provide data on year of registration for all cars registered in Norway. The quality of these data is assumed good. Functions that describe how age affects noise must be provided by SINTEF or other research institutions.

Data for local roads:
As mentioned earlier the Vegdatabanken only includes figures for national and provincial roads. Local roads are mostly not covered. In the 10 largest cities traffic counts have been performed and are available in VSTØY. It is not known what quality these data have and if also speed limits and percentage heavy vehicles are included. We propose to use these data (if available) in the model.

SN has made an estimate of the traffic flow on these roads based on the difference between the total traffic flow in (except for mopeds and motorcycles) from TØI (Rideng 2000) and traffic flow on national and provincial roads from the Vegdatabanken. In 1997 the total traffic flow was 29 mrd. km. Out of this about 26 mrd. km were from international, national and provincial roads This means that nearly 10 per cent of the traffic flow takes place on the local roads. This figure is highly uncertain.

In Vegdatabanken there are figures on vehicle kilometres in Norway. It is uncertain how suitable these data are to represent the national trend. Therefore we recommend using the trend in total vehicle kilometres from TØI to calibrate the data from Vegdatabanken.

4.2.2 Railway traffic
Data on the following noise determining parameters are available today, and can be applied in the first version of the model in 2001:

- Traffic flow
- Length of trains
- Types of train
- Speed
- Bridges and culverts
- Tunnels

All of these data are available from the Railway database, and from timetables (traffic flow and train types). Length of trains, which is important for measurements of Leq, can be found in the same databases. Traffic flow can, thus, be given as passings in metres per day. Freight trains are less predictable, and data on traffic flow, length of trains and types of train must probably be obtained for these sources separately. The NMT database contains noise emission data on all train types used in Norway, and the database is continuously updated with information on new trains.

Leq from a particular track unit can be calculated by the following general procedure:

1. A basic emission value is found on basis of traffic flow (including train lengths) and train speed
2. Emission values for each train type are corrected with factors from the NMT database
3. Correction factors related to the track unit is included (i.e. tunnels and bridges)

4.3 Propagation

Propagation of the generated noise from the source to the receivers is affected by many factors, i.e.:

- Screens
- Buildings between the source and the receiver
- Land cover
- Topography
- Insulation of facades and noise-reducing windows

A module will be made where distance from the road/track unit, screens, type of ground and windows are compensated for in the noise calculation:

$L_{Aekv} = L + \Delta L_D + \Delta L_{SCREEN} + \Delta L_{BUILD}$

where

ΔL_D	Distance correction; correction factor for the distance between the noise emission source and the receiver.
ΔL_{SCREEN}	Correction factor for screens
ΔL_{BUILD}	Correction factor for buildings between the source and the receiver

Since the SPI curves (see section 2.3.1) are made on basis of outdoor noise levels, we do not take into account building insulation and noise-reducing windows in the propagation and exposure calculations. This can be accounted for in later versions of the model if the SPI is further developed for indoor noise levels.

The calculations of noise propagation can be carried out by constructing perpendicular lines between the sources (track or road segments) and the receivers (address points). The different noise modifying factors can, thereafter, be calculated by using the breaks in the lines as a reference for reducing, or in some cases increasing, the noise level compared to the normal propagation curve. By applying this concept it is possible to attribute noise correction factors to single residences, and not only general factors attributed to all receivers within a defined exposure zone. In particular, this is suitable for detecting the noise-reducing effect of buildings between the source and the receiver.

A simplified version of the source-receiver line principle is shown in figure 4. The break in the line, caused by a building, leads to a reduction of noise (by a certain factor) compared to the normal propagation curve shown in the graph below. The principle is also exemplified in the case example in chapter 4.6, which also contains a stepwise calculation example based on the principle.

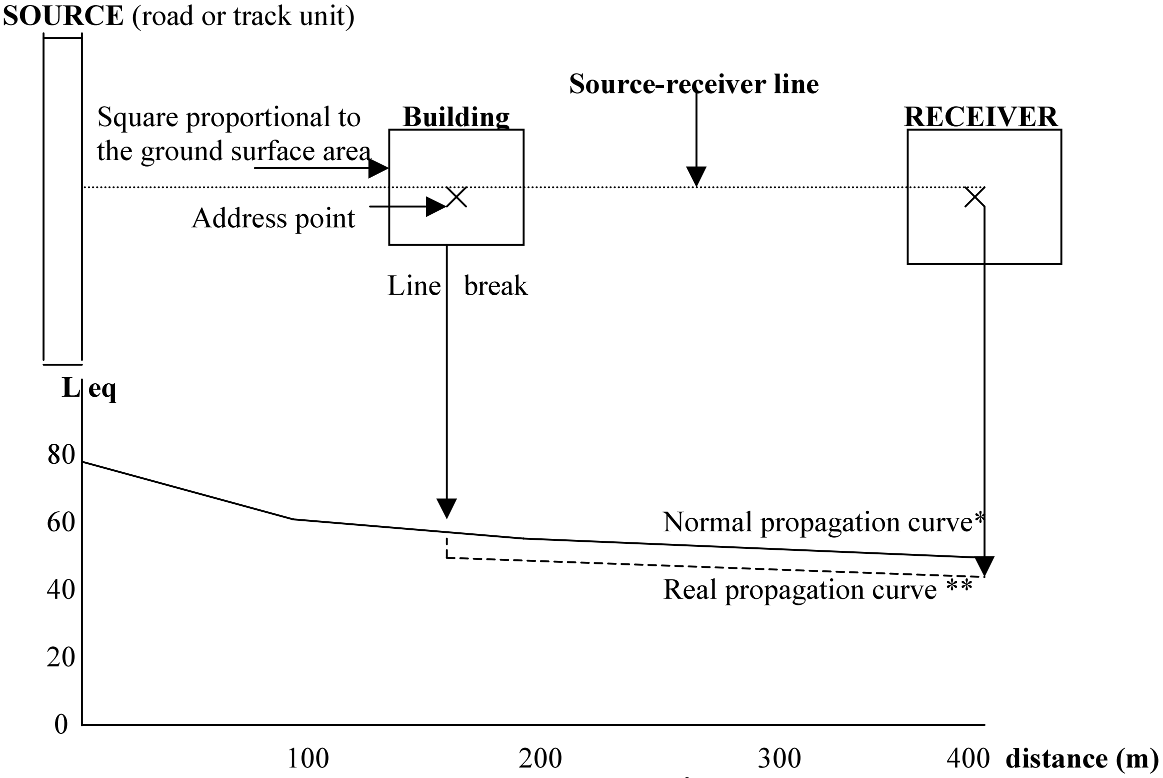
The source-receiver line principle may be applied on all address points within the defined exposure zones, thus, attributing noise exposure values to every single residence (or even resident) within the zones. There is, however, a possibility that this may lead to a data capacity problem, which can be avoided in two ways:

1. By estimating general noise-reducing factors for every defined exposure zone as a whole, thus assuming that all noise-modifying factors within every zone affects the receivers equally, only depending on the distance from the source (the segment).

2. By constructing source-receiver lines to all buildings as originally planned, but treating smaller areas at one time, i.e. municipalities, or even smaller areas, depending on traffic/population/road densities.

An alternative to this method (for road traffic) is to use the reduction figures calculated by VSTØY directly.

Figure 4. The "source -receiver line" principle



* Calculation premises: Speed: 80 km/h, Heavy vehicles: 10 per cent, ÅDT: 15 000. The curve is smoother in reality

** The curve is just a conceptualisation of a principle, and is not based on real values

BOX 4: Data sources for buildings and population

The official register for Ground properties, Addresses and Buildings (GAB):
GAB is under the responsibility of the Norwegian Mapping Authority, and comprises information on 2.3 million ground properties, 1.7 million addresses, and 3.4 million buildings. The municipalities are obliged to report to the register. For noise mapping purposes, the following parameters from the register are of interest:

- geo references (co-ordinates)
- type of building (classified)
- estimated ground surface of buildings
- building Id-number
- date of building taken in use

The Central Population Register (CPR):
The CPR is under the responsibility of the Norwegian Taxation Authority. The register is continuously updated, and a copy of the register is available in SN. The following parameter can be used in relation to noise mapping:

- Addresses and number of persons resident
- Age and sex
- Geo references matching the data in GAB

The Central Register of Establishments and Enterprises (BOF):
BOF is managed by SN. The register is linked to several administrative registers, and is also updated with survey information. The register contains geo-referenced information on activity (NACE) of enterprises. It also contains information on number of employees, which opens for noise exposure analyses based on people's actual locations through the day.

4.4 Exposure and annoyance

By the propagation calculations, noise exposure values are attributed to every address point (outdoor values). Since information from the Central Population Register (CPR) can be matched with information in the register for Ground properties, Addresses and Buildings (GAB) (see box 4), it is possible to identify the number of residents on each address, thus attributing the calculated address noise values to every resident.

This approach is relatively straight forward, as long as the receivers are not affected by more than one of each main sources of noise (international roads, national roads, provincial roads, railways and airports). Problems evolve when one receiver (address point) is exposed to two or more sources of the same type (treated in the same GIS layer), i.e. two municipal roads.

This problem may be solved in many ways. The most obvious way is to attribute codes to the different roads of the same type to separate them from each other. Another approach is to use the emission values, or other information already attributed to the sources, to separate them. Whatever solution will be selected, it will require additional work. It is therefore suggested to assess further the relevance of the problem, before deciding the appropriate way to solve it.

The exposure values attributed to every resident can be converted to annoyance values by the use of a Noise Annoyance Index (see chapter 2.3.1). The second report from this pilot-project describes a system to verify and to adjust the SPI according to Norwegian conditions (TØI 2000).

4.5 Integration of the air traffic sub-model

Except from the traffic at airport runways, noise emissions from aviation traffic differs from the two other sources in the way that it is three dimensional, and that it is not restricted to a physical constructed traffic network. Thus, the shape of the sources of aviation noise emission is complex to determine, and is highly dynamic compared to the two other sources.

To cope with this problem, it is suggested to make use of the results produced by the existing models on aviation noise, preferable the NORTIM model as direct input to the proposed model. The justification for this is that:

1. The existing model is considered to be of very good quality
2. There are few possibilities for further implementation of noise reduction measures related to aviation noise emissions (Luftfartsverket 1999)
3. Aviation noise contributes to only 5 per cent of the total number of people exposed to traffic noise in Norway (Luftfartsverket 1999).
4. There are relative safe predictions on noise emissions from aviation for the next years, and it is not expected that the noise emission situation will change significantly, with exception for a few airports.

It is therefor proposed to use the noise contours, which are currently produced by the NORTIM model, as a basis for the calculation of exposure. These contours can be used as basis in two alternative ways:

1. In their complete form. This implies that population will be the only variable that will be updated annually, while the noise contours will be static until they are reassessed every fourth year, or revised every eighth year. This is considered to be an acceptable approach, based on the justifications above, and the assumption that changes in the population within the noise zones will be the most significant factor affecting noise exposure. The population variable will be updated every year.

2. In their complete form with exception from the two main variables on noise emission: Amounts of traffic, and types of aircraft, which may be updated every year and used to modify the contours (by a simple factor).

A last alternative is to make a completely new model on aviation noise based on accessible yearly updated data. This option is, however, not considered as feasible due to high resource requirements in model development and operation compared with low expectations of a quality improvement.

4.6 Test case: People exposed to road traffic noise in the urban settlement of Askim

A simple test case has been run to exemplify the main principles of the model, and to outline the stepwise calculation procedure. The test case is based on the road network (from Vbase) and address points (from GAB) in the urban settlement of Askim (see figure 5). Except from these basic data, the figures presented in the case are dummy figures, and they serve only the purpose of exemplifying the general calculation procedures of the model. With reference to Askim, the proposed model and the calculation procedure can be described by the following:

1. Calculation of noise emissions from the road and railway units

Noise emission from every road/railway (source) unit is calculated from the activity data and equations presented in chapter 4.2. The values are given as Leq, which means that any point at the emission units produce the same amount of noise at any time (within the defined time period of the eq measurement). This is a premise to apply the source-receiver principle to measure noise propagation in the later stages.

For simplicity reasons, all units of the different sources of traffic noise (international roads, national roads, provincial roads and railway tracks) are given the same noise emission values in the case example. In the real model, emissions will be calculated for every single emission unit. The output of the emission calculations for the traffic network in Askim is shown in the first and second column in table 3.

Table 3. Output values for step one and two in the case example*

Noise emission units	Emission values	Exposure zone (distance from source)
International road units	85 Leq	400 m
National road units	80 Leq	250 m
Provincial road units	75 Leq	200 m
Railway track units	80 Leq	250 m

* The figures are not real values

2. Definition of exposure zones

The next step in the procedure is to limit the number of noise receivers (address points) to avoid unnecessary use of data capacity. This is achieved by defining a maximum limit of noise exposure at a certain distance from the sources, based on the emission values and the normal propagation curve (see figure 4). The limit can be defined where normal propagation has reduced the noise values to a certain level of Leq. Converted to metres from the emission units, the limits for Askim can be as shown in table 3, column 3.

All address points (dwellings) within these defined zones in Askim are shown as red dots on the map (figure 5). The number of address points and residents within the zones are shown in table 4.

Table 4. Number of address points and residents within the defined exposure zones in Askim

Sources of noise	**Addresses**	**Residents**
Provincial (County) roads	883	2826
National roads	1150	3708
International roads	1261	4213
Railways	695	2435
Total	3989	13182

Source: GAB and CPR

Figure 5. Address points (dwellings) within the noise exposure zone in Askim

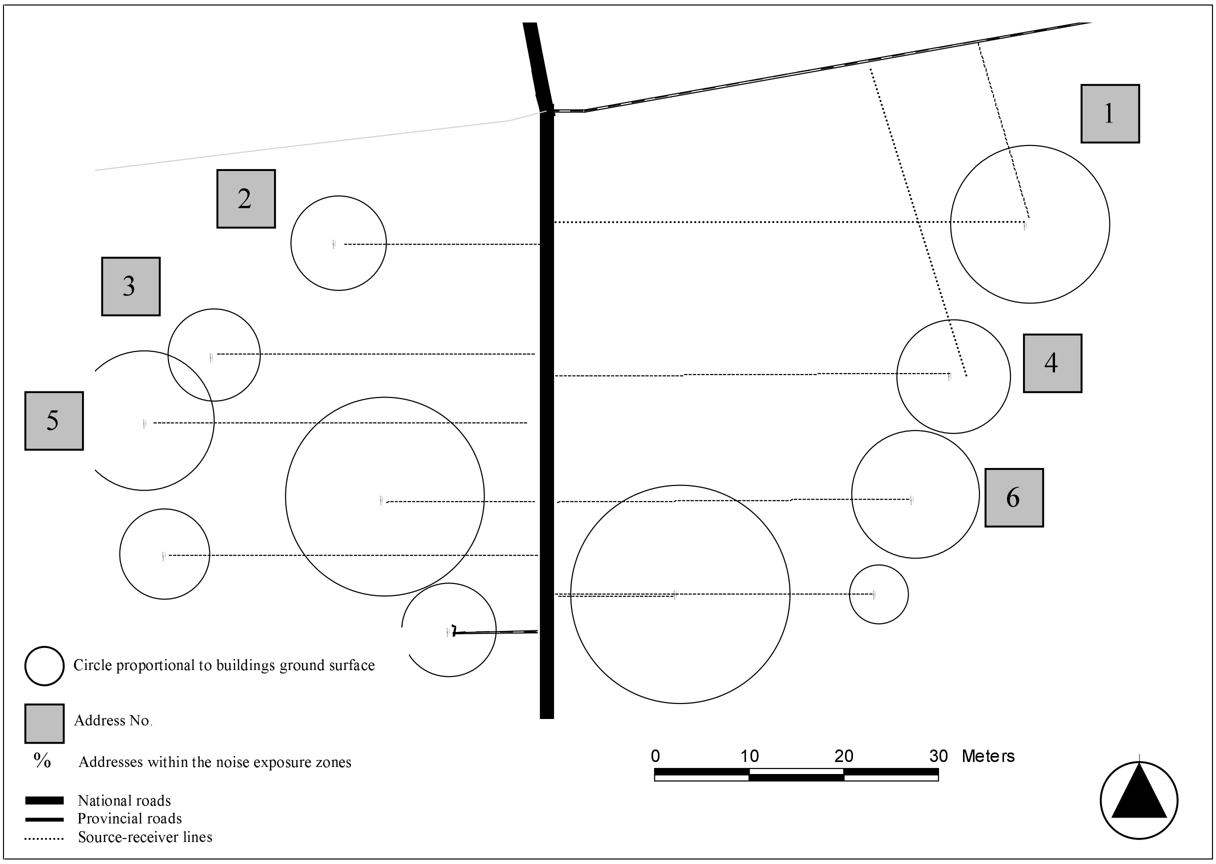
Source: Vbase and GAB

3. Construction of source-receiver lines and calculation of noise propagation

When all address points that theoretically can be exposed to a certain level of noise at their facades, are identified, source-receiver lines can be constructed between the different road/track units and the address points (at the shortest distance) to serve as a reference for the propagation calculations. The noise emission values are, thereafter, modified, compared to the normal propagation curve, according to different factors attributed to the different noise reducing elements between the source units and the receivers.

One important noise reducing element, affecting the residences in an area differently, is buildings between the receivers and the source. To apply the source-receiver line concept to measure the effect of interjacent buildings, it is necessary to visualise the area of the ground surfaces of the buildings on the GIS map. This information can be found in GAB (see box 4), but the data do not indicate the shape of the buildings, only the square surface areas. Thus, we make the assumption that all buildings are circular. This approach is visualised in a small-scale test site (figure 6), and a calculation example of propagation is given in table 5.

Figure 6. The test site*
(See figure 5 for location)



* The map is just a conceptualisation of a principle, and is not derived from a real map

Table 5. Calculation example of noise propagation in the test site area*

Addr	Sunit	Eunit	Dist	Pnm	Cbld	Cveg	Prl	Etot
1	nat. road	80	220	52	0	0	52	56
	prov. road	75	110	54	0	1	53	
2	nat. road	80	160	58	0	0	58	58
3	nat. road	80	190	54	0	0	54	54
4	nat. road	80	200	53	0	0	53	55
	prov. road	75	180	51	0	1	50	
5	nat. road	80	220	52	3	0	49	49
6	nat. road	80	190	54	3	0	51	51

* The figures are not real values

Addr - Address No.
Sunit - Source unit identification (road or track unit)
Eunit - Emission value from source unit (Leq)
Dist - Distance between source and receiver (m)
Pnm - Normal propagation (exposure value on facade) (Leq)
Cbld - Correction for interjacent buildings (Leq)
Cveg - Correction for vegetation (Leq)
Prl - Real propagation (exposure value on facades) (Leq)
Etot - Total exposure value on the facade (accumulated values) (Leq)

4. Calculation of annoyance

From the propagation calculations above, exposure values have been attributed to every single dwelling (address point). The number of residents registered on each address can be identified by comparing information in the CPR with information in the GAB. Thus, the number of people exposed to different levels of noise can be identified, and, thereafter, the number of people annoyed by traffic noise can be identified by the SPI (see figure 2). A calculation example based on the values in table 5 is given in table 6.

Table 6. Calculation example of people annoyed by traffic noise in the Askim test site area.

Address No.	No. of residents	Exposure value (Leq)	Annoyance score/SPI
1	5	56	0.29 * 5
2	2	58	0.32 * 2
3	3	54	0.27 * 3
4	3	55	0.28 * 3
5	3	49	0.21 * 3
6	2	51	0.24 * 2
Total	18		4.85

5 Further developments

There are three kinds of possibilities for improvement and further development of the proposed model. These are:

- *Quality assessments of the model*
- *Inclusion of new parameters and improved information*
- *Further analyses based on the model outputs.*

The different are summarised in this chapter.

5.1 Quality assessments

- Sensitivity analysis: This is to evaluate the importance of each parameter/variable and emission source for the trend in total annoyance. This can also include evaluation of the simplifications in the model.
- Calibration and verification of the model can be performed based on studies in specific areas by institutions like TØI and SINTEF. TØI has already proposed a system of linking exposure data to annoyance by a stratified sample for further investigations (TØI 2000), which will serve as a calibration tool for the proposed model.

5.2 Improvement opportunities

5.2.1 General improvement opportunities

- New knowledge of noise emissions and propagation may lead to recalculation of the exposure and annoyance data. This means that new knowledge may alter the figures for every year in the time series back to the base year of 1999.

- Evaluate if other types of exposure than exposure at dwellings should be taken into account. This could be a type of person exposure dose where for instance exposure in schools and kindergartens can be taken into account.
- SN has geo-reference data on both where people live and where they work. These data may be used in a calculation module for person dose of exposure for each source.
- L_{DEN}; modelling noise annoyance on a day/evening/night basis.
- Include more noise-emitting sources in the model such as industry, construction and harbour noise
- Utilise improved info on buildings and migration.
- Dominant wind direction is important for noise exposure. This may be taken into account in later versions of the model.

5.2.2 Road traffic

- To get good time series it is important, both for calculations of noise and emissions to air, with a large number of traffic counts on national and provincial roads. Continuous traffic counts should be performed on all important road sectors. Today data for local roads are lacking. These roads should also be included in the Vegdatabanken.
- It would be a great improvement for the model if more measurements of real speed were available. Real speed can deviate from speed limits.
- It is important that the surveys that gives figures on percentage of the cars that use studded tyres are performed annually also in the period 2000-2010.
- Snowfall and ice are two climatic factors that affect emissions.
- Changes in road elevation/topography (up- or downhill) affects noise emission.

5.2.3 Railway traffic

- Trams and subways are important sources of noise on urban and sub-urban areas, and can be included in the model at later stage.
- Curves in the track might have impact due heavier contact between the track and the wheels.
- Maintenance of wheels and tracks are assumed to be "normal" for all trains and tracks at present, but are quite important factors that affects noise emissions.

5.2.4 Air traffic

In the first version of the noise exposure model, it is recommended that the NORTIM noise contours are used directly, as a GIS layer, to state noise emission and propagation from air traffic. Population exposed within the different zones will, however, be updated annually from the GAB and the CPR. In future versions of the model there are two main opportunities for updating the NORTIM contours annually as well:

1. To modify the contours, according to an annual updating of traffic flow and types of aircraft.

2. To make annual total reassessments of the contours.

Option number one will be considered from the beginning, but option number two is considered beyond the scope of the model.

The model may also be extended with other sources of noise, i.e. noise from heliports.

5.2.5 Further development of the population exposure variable

All noise models presented in this document, as well as the first version of the model we propose, are based on the assumption that residents stay in their dwellings 24 hours a day. This is, off course, not the case. As long as the national objective on noise reduction is stated as "*people* annoyed by noise", it should be made efforts to map where people stay during the different periods of the day, and this information should be included in the noise models.

By combining information from the CPR and the GAB, it is already possible to make some assumptions on the resident's movements during the day. In its simplest form, this can be done by assuming that residents of certain age groups are busy at work, school or kindergartens, etc. in periods of the day, thus, they are not affected by noise in their residences.

Institutions like schools, kindergartens, hospitals, nursing homes, etc can be included in the model based on information in the GAB. Information on the number of employees in enterprises is found in the Central Register of Establishments and Enterprises (BOF). There are also on-going projects aimed to connect information from the CPR and the BOF, which will link resident id-numbers to both addresses and working places.

The databases on population activities are constantly improved, and it is assumed that this will lead to substantial better possibilities to analyse real noise exposure.

5.3 Analyses

A range of analyses may be carried out based on the outputs of the model. Some examples are:

- Analyses of relationships between socio-economic parameters and noise levels.
- Calculations of economic costs related to noise emissions.
- Projections (estimation of future noise levels).

6 Conclusions

It is possible to develop an indicator model for monitoring noise emission, propagation, exposure and annoyance as described in chapter 2.2 (Objectives). The model will be based on existing data, but it will be flexible and open-ended. Results from new research projects will be taken into account.

The model will give data for the years 1999-2010. Data for the whole time series may be calculated annually. The annual updates are likely to be carried out within a month's work. This means that if new knowledge emerge, on for instance noise from different car types in a certain year, new levels of exposure and annoyance will also be calculated for all the former years. It will be possible to produce figures for the years 1990 (as a reference) and 1999 by 2001.

We can conclude that the proposed model will:

- Take into account exposure from several noise-emitting sources.
- Focus on aggregated data (national level first, later data for counties may be provided).
- Be easy to update on an annual basis.
- Be specially suited for monitoring annual changes.
- Be cost-efficient.

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