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*TNO, Business Unit Mobility & Logistics*
*PO Box 49*
*2600 JA Delft*
*The Netherlands*
*Telephone: +31 15 269 7393*
*telefax: + 31 15 269 6854*
*email: isabel.wilmink@tno.nl*

IMAGINE
Improved Methods for the Assessment of the Generic Impact of Noise in the Environment

# Guidelines for the use of traffic models for noise mapping and noise action planning

***Deliverable 7* of the IMAGINE project**

***(WP2: Demand and traffic flow management)***

WP-leader: TNO

Project Co-ordinator: AEA TECHNOLOGY RAIL BV

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|---|---|---|---|
| WP2 partners: TNO, ULeeds, UGent, TML, M+P, Leicester | 060531 | WP2 partners<br>Brian Hemsworth<br>Greg Watts | 060608<br>060713<br>060630 |

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| TNO | 2 | Isabel Wilmink (WP leader) | 06-06-08 |
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## EXECUTIVE SUMMARY

In the IMAGINE (Improved Methods for the Assessment of the Generic Impact of Noise in the Environment) project, guidelines, examples and databases that allow for a quick and easy implementation of the harmonised noise computation methods in the Member States of the European Community are provided. The IMAGINE project is closely linked to the Harmonoise project, in which these harmonised computation methods were developed. Whilst the Harmonoise project focused on prediction methods for road and railway noise, the IMAGINE project extends this range with aircraft and industrial noise sources.
The products of Harmonoise and IMAGINE are intended to provide a valuable input to the Commission and Member States, in order to establish legally binding common assessment methods as foreseen by article 6 of the Environmental Noise Directive (END). This harmonisation process, which needs formal agreement in the context of a regulatory committee, might intervene in the coming years in order to enforce common methods that will have to be used for the second round of noise mapping (2012). For the first round of noise mapping (2007), interim methods mentioned in Annex II of the END, or national methods that are equivalent to these interim methods, have to be applied. The methods can also be used for any other purpose of community noise prediction.

***Work package 2: Demand and traffic flow management***
This is the final deliverable of work package 2 of the IMAGINE project, titled *Demand and traffic flow management*. The purpose of this report is to assist authorities and consultants in using traffic models to produce road traffic data for noise mapping and noise action planning, undertaken to produce the data as required by Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 (the END). Traffic models are needed because in most cases it will be impossible to construct a noise map without any form of traffic modelling. There is usually simply not enough measured traffic data. Also, in noise action planning, a traffic model is needed to determine the expected effects of measures.

***Background information***
The first part of this report gives general introductions to noise and traffic modelling, and explains how traffic models are used in the context of noise modelling. The introduction to noise models gives general information about noise calculations and the Harmonoise/IMAGINE road noise source model and its data needs. In order of importance (to the accuracy of the noise calculations), these are:

1. vehicle speeds & traffic composition;
2. vehicle flows;
3. acceleration/deceleration;
4. speed distributions
5. (data regarding the above parameters on) low flow roads.

The introduction to traffic modelling discusses the characteristics and application of different traffic model types, and discusses the reliability of the traffic data they provide.
The final chapter of part I describes the process of traffic modelling in the context of noise modeling and what problems can arise when traffic models are used to produce data for noise modelling exercises.

***Guidelines for the use of traffic models***

The second part of the report gives the guidelines that have been developed to deal with the problems discussed in part I. These are recommendations on how to improve common types of traffic models, in order to provide accurate traffic data for the Harmonoise/IMAGINE road noise source model (for yearly averages and separately for day-evening and night-time periods). They were written for authorities and consultants working in the field of traffic and transport as well as noise mapping and noise action planning. With this report, they should be able to:

- judge whether the traffic model available can (in theory) deliver the desired data, with acceptable accuracy;
- choose an appropriate traffic model (for noise mapping of main roads or of agglomerations, or for noise action planning); and
- review which possibilities there are for improvement of the traffic model and where more information can be found on how to implement these improvements.

Also, some guidance is given for the situation in which no traffic model is available.

Some elements of this deliverable, that are not specific to the 'Harmonoise/IMAGINE methods', may be helpful for the 2007 round of END mapping with other methods, provided that if there is any discrepancy between this deliverable and the Good Practice Guide V2, it is the advice in the Good Practice Guide V2 that should be used for the other methods.

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# PART I: BACKGROUND INFORMATION ON THE USE OF TRAFFIC MODELS FOR NOISE MAPPING AND NOISE ACTION PLANNING

# 1 Introduction

## 1.1 Context / IMAGINE project

Environmental noise is a topic of growing concern in Europe, both on a central policy level and amongst European citizens. In spite of noise regulations and legislation that have existed for a long time in many member states, the number of European citizens that are annoyed by environmental noise shows an ever growing tendency. Serious annoyance has been demonstrated to cause serious health problems and a reduction of the amount of healthy life span for citizens in Europe.
The European Parliament, in its reaction to the Green Paper on Future Noise Policy, noted among others the lack of reliable, comparable data regarding the situation of various noise sources in Europe. The Environmental Noise Directive (2002/49/EC) responded to that by defining a common, harmonised set of noise indicators and a common approach to the production and presentation of noise data from the member states.

The IMAGINE project, *Improved Methods for the Assessment of the Generic Impact of Noise in the Environment*, will provide guidelines, examples and databases that allow for a quick and easy implementation of the harmonised noise computation methods in the Member States of the European Community. The IMAGINE project is closely linked to the Harmonoise project, in which these harmonised computation methods were developed. While the Harmonoise project focused on prediction methods for road and railway noise, the IMAGINE project extends this range with aircraft and industrial noise sources and with ready-to-use values and databases for all sources

The products of Harmonoise and IMAGINE are intended to provide a valuable input to the Commission and Member States, in order to establish legally binding common assessment methods as foreseen by article 6 of the Environmental Noise Directive (END). This harmonisation process, which needs formal agreement in the context of a regulatory committee, might intervene in the coming years in order to enforce common methods that will have to be used for the second round of noise mapping (2012). For the first round of noise mapping (2007), interim methods mentioned in Annex II of the END, or national methods that are equivalent to these interim methods, have to be applied.

## 1.2 This deliverable

### 1.2.1 Objectives and target group of the guidelines

This is the final deliverable of work package 2 of the IMAGINE project, titled *Demand and traffic flow management*. The purpose of this report is to assist authorities and consultants in using traffic models to produce road traffic data for noise mapping and noise action planning, undertaken to produce the data as required by Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002, relating to the assessment and management of environmental noise. This directive is commonly known as the Environmental Noise Directive (END).
Traffic models are needed because in most cases it will be impossible to construct a noise map without some form of traffic modelling. There is usually simply not enough measured traffic data.

Also, in noise action planning, a traffic model is needed to determine the expected effects of operational measures.

The guidelines give recommendations on how to improve common types of traffic models, in order to provide accurate traffic data for the Harmonoise/IMAGINE road noise source model. It is not the purpose of this report to recommend specific models. Also, this report does not give guidance for the situation in which there is no traffic model available. For this situation, the reader is referred to deliverable 5 of the IMAGINE project, *Standard test methods for the experimental assessment of noise levels* [forthcoming] and the Good Practice Guide [WG-AEN, 2006].

This report was written for authorities and consultants working in the field of traffic and transport on the one hand, and noise mapping and noise action planning on the other hand. Traffic engineering practitioners and acousticians often work together on noise calculations, and it is important that both parties have knowledge about the strengths and weaknesses of traffic models in the context of noise mapping and noise action planning. With this report, they should be able to:

- judge whether the traffic model available can (in theory) deliver the desired data, with acceptable accuracy;
- choose an appropriate traffic model (for noise mapping of main roads or of agglomerations, or for noise action planning); and
- review which possibilities there are for improvement of the traffic model and where more information can be found on how to implement these improvements.

Also, some guidance is given for the situation in which no traffic model is available.

Some elements of this deliverable, that are not specific to the 'Harmonoise/IMAGINE methods', may be helpful for the 2007 round of END mapping with other methods, provided that if there is any discrepancy between this deliverable and the Good Practice Guide V2, it is the advice in the Good Practice Guide V2 that should be used for the other methods.

### 1.2.2 Structure of this report

This report contains is divided into two parts:

I. Background information on the use of traffic models for noise mapping and noise action planning; and
II. Guidelines for the use of traffic models for noise mapping and noise action planning.

The first part gives general introductions to noise and traffic modelling (chapters 2 and 3). The introduction to noise models gives general information about noise & noise modelling, and the Harmonoise road noise source model and its data needs. The introduction to traffic models discusses the characteristics and application of different traffic model types, and discusses the reliability of the traffic data they provide.
Furthermore, in part I, chapter 4 explains how traffic models are used in the context of noise modelling. The steps to be taken in the traffic modelling process in the context of noise modelling are discussed, and insight is given into common problems arising when traffic models are used to produce data for noise modelling exercises.

The second part gives the guidelines that have been developed to deal with the problems discussed in part I. Chapter 5 outlines the possible applications of traffic models for noise modelling, and directs the reader to specific guidelines. The guidelines are sorted by purpose (noise maps for main roads, noise maps for agglomerations, action planning), model type (macroscopic/microscopic) and by problem area (speed, acceleration, traffic composition, diurnal and long-time patterns, low flow roads, intersections and gradient). Chapter 6 gives guidelines for the use of traffic models for noise mapping for main roads. Chapter 7 gives guidelines for the use of traffic models for noise mapping for agglomerations. Chapter 8 gives guidelines for the use of traffic models for noise action planning.

In the annexes, a glossary (Annex 1), a checklist for the choice of an appropriate traffic model and for the reporting of the traffic modelling process (Annex 2) and the executive summaries of and references to the four task reports providing background material (Annex 3) can be found.

## 1.3 The place of WP2 in IMAGINE

The global structure of the Harmonoise and IMAGINE methods is given in the schematic overview in Figure 1. A clear separation is made in the model between the source descriptions for road, rail, industry and aircraft sources, and propagation away from the source. The result of the source models is a sound power level per source type for each source height relevant to that source, together with a certain directivity.

The P2P model, describing the sound propagation via a predefined path from one source point to one receiver point, is the basis of the propagation model. The selection of the P2P paths is made in the propagation method itself. The model also describes how meteorological conditions influence the shape of one propagation path.

The result of the propagation model is an $L_{eq}$ level at a specific receiver point for a given meteorological class. The total $L_{eq}$ from a source is the summation of the contributions of the different sub sources (located at different heights) via their respective propagation paths.

The $L_{den}$ ($L_{night}$) value is calculated from the $L_{eq}$ values by determining the occurrence of the different meteo classes within the time period of assessment, and summing the relative contributions of each class.

WP2, addressing traffic models, provides means of obtaining input data (flows, speeds etc.; the yellow ‘traffic flow’ box in Figure 1) for the road source model (the orange ‘source’ box in Figure 1) to determine the relevant sound power level.

Traffic models can, depending on the type of model, provide aggregated flow data (e.g. flows and speeds per hour or per period of the day) or individual vehicle data (e.g. vehicle type, speed and acceleration per second) for the road sections included in the noise calculations. Both can be handled by the source model, but when the traffic data is provided to the source model in the form of individual vehicle data, the resulting noise levels from individual vehicles need to be aggregated to obtain the noise levels for the desired periods of the day.

The traffic data should be provided in such a way that yearly averages, and separately for the day, evening and night-time periods, can be determined.

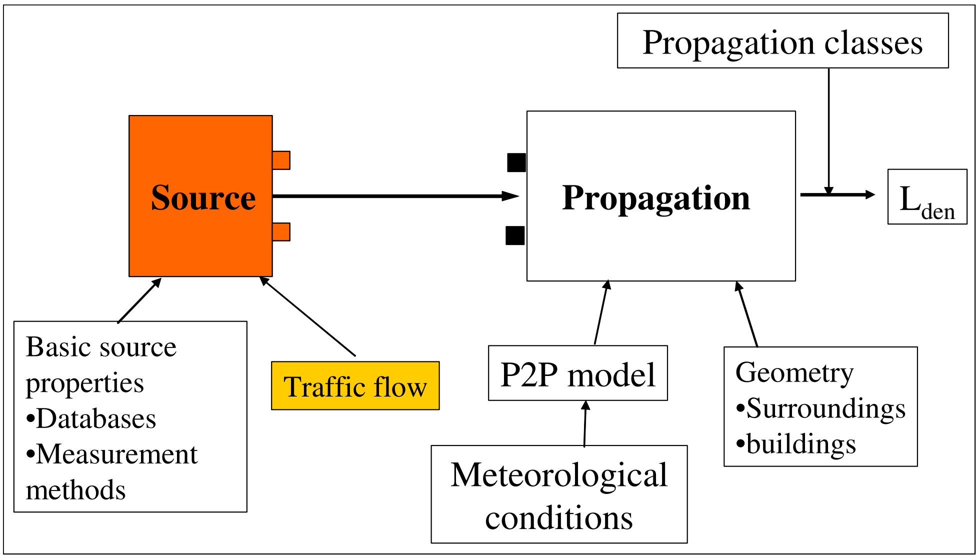



**Figure 1: Schematic overview of the IMAGINE project and the place of WP2 in it.**

## 1.4 Relationship between Deliverable 7 of IMAGINE and the GPG of WG AEN

It is important to appreciate that this report (Deliverable 7 of the IMAGINE project) has been developed specifically for use with the products of Harmonoise/IMAGINE. The Good Practice Guide (GPG) Version 2 produced by WG-AEN was developed specifically for the use with the Interim Methods (NMPB / XPS for road traffic) or current adapted National methods to help MS to carry out the noise mapping for the END in 2007. However, there are some elements of D7 that are general in nature (especially concerning the use of traffic models) and may provide a helpful supplement to the contents of the GPG Version 2. The following summarises the applicability to END mapping 2007 of the various sections of D7:

Section 2 - Not applicable to 2007 END mapping.

Section 3 - General, may be applicable in 2007.

Section 4 - Some parts are general and may be applicable in 2007, although some data requirements are specific to IMAGINE / HARMONOISE only.

Sections 5 & 6 - Specific to IMAGINE / HARMONOISE - use GPG instead in 2007.

Section 7 - Some general information may be helpful to supplement the GPG, but only where the GPG itself does not provide an alternative approach.

Section 8 - General information on traffic models, so applicable in 2007 as well as for IMAGINE/HARMONOISE.

Annexes - These describe other work packages in IMAGINE and so are not relevant to END mapping in 2007.

# 2 Introduction to noise models

## 2.1 Introduction to noise & noise modelling

### 2.1.1 dB scale

Sound levels are expressed on a logarithmic scale in decibels (dB). Such a logarithmic scale is chosen since it lies closely to the human perception of the amplitude of acoustic waves.
The strength of an acoustical source is quantified by its source power level, $L_w$, and is defined as

$$L_W = 10 \cdot \log_{10}\left(\frac{W_{rms}}{W_0}\right)$$

where $W_{rms}$ is the root mean square of the acoustical power of the source, and $W_0$ is the reference power which usually equals 1 $10^{-10}$ Watt.

The sound pressure level $L_p$ is an indication of the strength of an acoustic pressure wave at a receiver and is calculated as

$$L_p = 10 \cdot \log_{10}\left(\frac{p_{rms}^2}{p_{ref}^2}\right),$$

where $p_{rms}$ is the root mean square of the amplitude of the pressure wave and $p_{ref}$ is usually equal to $2 \cdot 10^{-5}$ Pa. The acoustic energy of a sound wave is proportional to $p^2$.

Some rules of thumb concerning the perception of differences in $L_p$ are as follows. A difference of 1 dB is hardly perceived by the human ear, while a difference in 3 dB, equal to a doubling of the acoustic energy, is observed as a small increase. A difference of 10 dB is perceived as a doubling of the loudness.

### 2.1.2 A-weighting

The human ear does not have the same sensitivity for all frequencies in a sound. Sounds with frequencies of a few thousand Hertz are perceived louder than sounds containing mainly low frequencies and very high frequencies. To take this difference in sensitivity into account, the sound registered by a microphone is filtered using an A-weighting filter. The resulting sound pressure level is expressed in dB(A).

### 2.1.3 Equivalent sound pressure level

Traffic noise levels usually vary quickly over time. The equivalent sound level, $L_{eq}$, is defined as

$$L_{eq} = 10 \cdot \log_{10}\left(\frac{1}{T}\int_{t_1}^{t_2} \frac{p_{rms}^2(t)}{p_{ref}^2}\,dt\right).$$

This $L_{eq}$ is defined as the sound level of a constant sound which contains the same acoustic energy as in the time-varying signal over the time period $T = t_2 - t_1$. The exact value of $L_{eq}$ depends on the length of the time period $T$. $p_{rms}(t)$ is the root mean square of the pressure of the time-varying signal, $p_{ref}$ is the reference pressure level (=$2 \cdot 10^{-5}$ Pa).

### 2.1.4 $L_{den}$

The concept of the equivalent sound pressure level is of particular importance since it forms the base of the noise indicator $L_{den}$ proposed by the EU noise directive. $L_{den}$ is defined as:

$$L_{den} = 10 \cdot \log_{10}\left[\frac{12}{24}10^{\frac{L_{day}}{10}} + \frac{4}{24}10^{\frac{L_{evening}+5}{10}} + \frac{8}{24}10^{\frac{L_{night}+10}{10}}\right],$$

where $L_{day}$, $L_{evening}$ and $L_{night}$ are the A-weighted long-term average sound levels, determined over respectively the day periods (12 hours, by default from 07:00 till 19:00), evening periods (4 hours, by default from 19:00 till 23.00) and night periods (8 hours, by default from 23:00 till 7:00). Member states may shorten the evening period with one or two hours and lengthen day/night accordingly. As seen from the formula above, the sound pressure level during the evening period is increased ('punished') with 5 dB, and the level at night with 10 dB. In this way, the increase of the impact of noise during the night and the evening ('rest'-period) is accounted for to a certain degree.

The choice of $L_{den}$ as a common indicator has some important consequences for what is expected from traffic flow models generating the basic data. Traffic data is needed in theory at different moments in a 24-hour period.

The use of $L_{night}$ as a common indicator necessitates the need for traffic data over the night period. Historically, traffic models have not been overly concerned with overnight flows. The additional penalisation of $L_{night}$ levels by 10dB(A) may compensate the typical lower traffic intensities in that period. Larger relative uncertainties about night-time traffic movements will increase the overall uncertainty in $L_{den}$ values. This presents a challenge for traffic modellers.

## 2.2 Data needs of noise models

### 2.2.1 Summary of the noise model

***Single vehicle source model***

The HARMONOISE noise emission model for road traffic, being further developed in IMAGINE Work Package 5, can be summarised as follows:

- The model is designed to calculate the *instantaneous* emitted noise (expressed in terms of sound power level) for *one single vehicle* at the *source points* as a function of the vehicle category and additional vehicle parameters, driving behaviour, road surface parameters, and meteorological conditions.
- Each vehicle category is represented by two point sources, each having a specified sound power $L_W$, having contributions from rolling noise and propulsion noise as a function of the vehicle speed $v$ in km/h. Aerodynamic sources are incorporated in the rolling noise source. These main equations are:

  rolling noise: $L_{WR} = a_R(f) + b_R(f) \cdot \lg\left[\frac{v}{v_{ref}}\right]$ with $v_{ref} = 70$ km/h ;

  propulsion noise: $L_{WP} = a_P(f) + b_P(f) \cdot \left[\frac{v - v_{ref}}{v_{ref}}\right]$ with $v_{ref} = 70$ km/h .

- The main source levels of rolling and propulsion noise are then distributed over two point sources. For propulsion noise, 20% of the sound power is appointed to a point source at 0,01 m height, and 80% is appointed to the second noise source at 0,3 m or 0,75 m for light and heavy vehicles, respectively (see Figure 2). For rolling noise 80 % of the sound power is appointed to the lower source point at 0,01 m, while 20 % is appointed to the higher source points (0,30 m for passenger cars and 0,75 m for heavy vehicles).

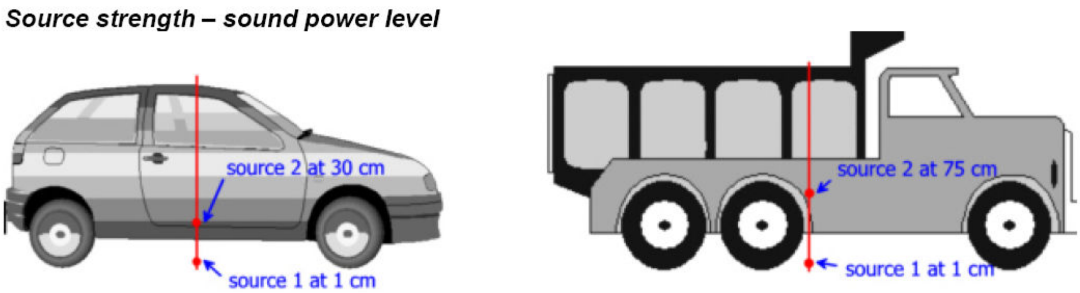



**Figure 2: Positions of noise sources on vehicles**

- As a minimum 4 vehicle categories are used:
  - passenger cars;
  - medium heavy vehicles, trucks and buses with two axles;
  - heavy vehicle, trucks and buses with 3, 4 or more axles; the emission coefficients $a_p(f)$ are based on 4 axles and comprise a correction for other axle numbers;
  - powered two-wheelers (motorcycles, mopeds)
- All default data refer to a reference condition: constant speed, 20 °C and the average of DAC 0/11 and SMA 0/11 road surface. Deviations from these conditions are corrected for.

***Correction factors***

The HARMONOISE description of the source model also gives a number of correction factors for deviations from this reference condition. The correction factors are listed below. For more detailed information, see [HARMONOISE, 2004].

- *Directivity*: variations of source radiation as a function of horizontal and vertical angle;
- *Temperature*: the rolling noise is to be corrected for the air temperature, where the correction is dependant on the road surface type;
- *Tyre type*: a correction for studded winter tyres, of the form $\Delta L = a(f) + b(f) \cdot \lg(v)$ with *a* and *b* known as a function of frequency;
- *Road surface*: corrections for the road surface are dependant on frequency, vehicle category and vehicle speed, and are usually in the form $\Delta L = a(f) + b(f) \cdot \lg(v/v_{ref})$; $v_{ref}$ is the reference speed, defined as 70km/h.
- *Acceleration/deceleration*: the rolling noise is assumed not to depend on acceleration or deceleration. For propulsion noise, a correction is given by $\Delta L = C \cdot a$, where the acceleration *a* is expected not to exceed the range from -2 to +2 $m/s^2$. The coefficient C is given for the overall level per vehicle category, but may be given as a function of frequency in the final model;
- *Regional variations*: The HARMONOISE description of road noise source modelling, as described in [HARMONOISE, 2004], contains a set of coefficients to calculate the noise emission of a road vehicle. All coefficients are average values, based upon measurement data from various European countries. In some regions, however, the average values for these coefficients may deviate to some extent as a result of differences in the 'average' traffic situation in this region. Factors that are region-dependant are:
  - average vehicle weight;
  - composition of engine types;
  - average vehicle age and state of maintenance;

- typical tyre composition: as indicated in the HARMONOISE description;
- average composition of each vehicle class.

***Aggregation to vehicle flow***

The source emission model, as described above, gives the instantaneous sound power level for a single vehicle at a specific point, given the vehicle class, and its speed and acceleration. To calculate the noise emission of a vehicle flow on a network link, the instantaneous, single-vehicle sound power level $L_W$ needs to be translated to an *equivalent sound pressure level*, $L_{eq}$, which is the sound pressure level at a receiver position averaged over a certain time period.

In order to execute the above mentioned computation in principle one should carry out the following steps:

- Compute the noise impact of each individual vehicle at the receiver point as a function of time while the vehicle passes along the network link;
- Integrate the contribution of each vehicle over time;
- Sum the contribution of all vehicles passing over the network link during a certain time interval;
- Determine the average noise impact of the vehicle flow during the specified time interval.

If one assumes a steady flow of vehicles on the network link with an average speed $v$ at each moment in time there will be a number of $Q/v$ vehicles per unit length, where Q is the number of vehicles passing per unit time. Instead of integrating over time one may also integrate over the length of the network link and obtain an equivalent result for the noise impact. Therefore it may be useful to express the noise emission of the vehicle flow in terms of an equivalent line source strength (average sound power per unit length) $L_{W,\,line,\,eq}$, as follows [HARMONOISE, 2002A] and [HARMONOISE 2002b]:

$$L_{W,line,eq} = L_{W,0} + 10 \cdot \lg\left(\frac{Q}{v}\right),$$

where $L_{W,0}$ is the instantaneous sound power level of the rolling noise or the propulsion noise of a single vehicle according to the formulae in 2.2.1. $L_{W,\,line,\,eq}$ is expressed in dB (re. $10^{-12}$ W) per m, Q in vehicles per second and $v$ in m/s. This may be converted from other units by introducing conversion constants; if $Q$ is given in vehicles per hour and $v$ in km/h, then divide $v$ by 1000.

For noise impact computations the sound emission of the moving vehicles on the network link may be represented by a series of incoherent point sources, distributed evenly over the network link. The sound power of each of these point sources must be equal to: $L_{W,\,line,\,eq}$ + 10 lg $l$, where $l$ is the length of the network section that is represented by the point source. Usually two series of incoherent point sources at different heights will be used to represent the rolling noise as well as the propulsion noise of the vehicle flow on one traffic lane. Traffic lanes may be added together into composite driving lines and, consequently, composite series of point sources.

It should be noted that this definition of *equivalent* line sound power levels thus includes the influence of the pass-by time of the vehicle. Thus, a vehicle passing by at a lower speed will be heard longer, which has an increasing effect on the *equivalent* sound power level $L_{W,line,eq}$. This will thus raise the sound levels of slow traffic relative to those of fast traffic. Since fast vehicle produce higher *instantaneous* sound power levels the two effects are opposing, resulting in a minimum in the $L_{W,line,eq}$ vs. $v$ curve around 20 km/h.

Using the equation above, the equivalent line sound power levels for different groups of vehicles (e.g. by vehicle or speed class) or different lanes can be mutually compared and summed. The summation of equivalent line sound power levels is calculated as follows:

$$L_{W,eq,total} = 10 \cdot \lg\left[\sum_{i=1}^{N} 10^{L_{W,eq,i}/10}\right],$$

where $L_{W,eq,i}$ are the $N$ separate equivalent line sound power levels to be added. Similarly, the <u>average</u> equivalent line sound power level of multiple $L_{W,eq,i}$ values is calculated by:

$$L_{W,eq,avg} = 10 \cdot \lg\left[\frac{1}{N}\sum_{i=1}^{N} 10^{L_{W,eq,i}/10}\right] = 10 \cdot \lg\left[\sum_{i=1}^{N} 10^{L_{W,eq,i}/10}\right] - 10 \cdot \lg N .$$

### 2.2.2 List of required traffic data

From the model, as described above, it is made clear that various input parameters are necessary. Some of these parameters (such as road surface, % studded winter tyres, etc.) will have to be supplied directly by the local or national authorities. From the traffic modelling, the main parameters that have to be delivered are the speed and acceleration per vehicle class, and the number of vehicles in each class. A more specific and full list of required traffic variables is given in Table 1 below.

**Table 1: Traffic parameters required by the road noise source model.**

| parameter | description | unit |
|---|---|---|
| vehicle flow (intensity):<br>- for passenger cars<br>- for light trucks<br>- for heavy trucks<br>- for powered two-wheelers | the total number of vehicles per vehicle class, per time unit, for the entire road or road lane;<br>time unit is usually one hour, vehicle speed is usually given in km/h (see section 2.2.1)<br>note that a separate vehicle flow number is needed for light and heavy trucks | $h^{-1}$ |
| vehicle speed:<br>- for passenger cars<br>- for trucks<br>- for powered two-wheelers | the driving speed of the vehicles per vehicle class, which can be given as:<br>- one “spot” speed value for each single vehicle<br>- a speed distribution, where an average speed value is given for successive speed ranges, and the % of vehicles for each range[1]<br>- an average speed for the whole vehicle class | km/h |
| vehicle accel./deceleration:<br>- for passenger cars<br>- for trucks<br>- for powered two-wheelers | the acceleration value per vehicle class, being negative for decelerating vehicles, which can be given as:<br>- one value for each single vehicle<br>- a distribution, where an average acceleration is given for successive ranges, and the % of vehicles for each range[2]<br>- an average acceleration for the whole vehicle class | $m/s^2$ |

[1] for example: 5% of the vehicles drive at an average of 5 km/h, 15% at 15 km/h, 20% at 25 km/h, etc.
[2] for example: 15% of the vehicles accelerate at an average of 2 to 1 $m/s^2$, 45% from 0,5 to 1 $m/s^2$, 40% at 0 to 0,5 $m/s^2$

***Using speed and acceleration data***
Due to the logarithmic nature of noise, vehicles with higher noise emission will contribute more to the total emission than vehicles with lower noise emission. Furthermore, the dependence of the road noise emission on vehicle speed is non-linear (see 2.3.1). Both these factors require some care in calculating the total noise emission of a vehicle flow: the total noise emission of a vehicle flow with 1000 vehicles driving at different speeds from 60 to 80 km/h is *not* the same as that of 1000 vehicles driving at 70 km/h.

The noise model assumes that the speed values used in the calculation are the instantaneous "spot" speeds (as if measured by a speed radar at the point of interest) for each single vehicle. If a model is available that can deliver such data, the best way to go is always to calculate the equivalent noise level for each vehicle or smallest group of vehicles first, and then calculate the energy sum of these noise levels to acquire the total noise emission.

If a less detailed model is available, i.e. only average speed values for groups of vehicles or for an entire vehicle flow, an error of 0 – 1 dB(A) is introduced with respect to the actual total noise emission of all the separate vehicles. The real noise emission will generally be underestimated by the model, unless the vehicle speeds are below 20 km/h.

For acceleration, the same can be said: less detailed or averaged data will introduce an error with respect to modelling individual vehicles.

## 2.3 Important parameters of the Harmonoise road noise source model

The traffic parameters listed in 2.2 influence the source power emitted by traffic, and therefore the accuracy of the resulting noise map. Based on findings in previous reports, it can be stated that the main traffic parameters (that should be available in all situations) are **traffic intensity (flow)**, **traffic speed** and **traffic composition**. For noise mapping of urban roads, the use of **acceleration/ deceleration** data, in addition to the above traffic parameters, leads to further improvements. Correction factors can be used in case the traffic model is not able to provide this data. The importance of low flow roads in urban context depends on the required accuracy at lower exposure levels. Further improvements in the accuracy of noise mapping of both major and urban roads may come from including **speed distribution**, and from accounting for **variations in flow patterns over time**.

The sensitivity of the output of the traffic noise source model to the traffic input parameters was quantified in previous reports. In a first approach (see Section 2.3.1), the accuracy demands for individual traffic parameters are assessed. Such an analysis assumes that a certain accuracy level for one parameter is only valid if the other parameters are fully accurate. An accuracy goal of 1dB(A) is proposed. It is however important to realise that the accuracy requirements on traffic parameters interact. So, in order to fulfil an overall accuracy of 1 dB(A), it is not enough to establish each of the given accuracies separately; the total deviation of the result could be much higher, or alternatively, cancel each other out. Therefore, some case-studies were performed to learn how accuracy demands on traffic parameters behave in realistic situations (see Section 2.3.2). The analysis of accuracy requirements on individual parameter stays however valuable, since analysis of combined errors is often complex and depends on the situations that were modelled.

The importance of temporal resolution was studied strictly on the emission side, and was linked to time-dependent propagation conditions (see Section 2.3.3).

### 2.3.1 Analysis of individual traffic parameters

***Intensity***

For long-time equivalent noise levels, the dependence on the number of vehicles passing is simply logarithmical. Therefore a doubling of the total traffic intensity, given a constant average speed and fleet composition, results in an increase of 3 dB. An accuracy of ± 1 dB requires the total intensity to be accurate within ± 25%.

***Speed***

The noise emission of a single vehicle increases with its speed in a rather complicated manner, since the speed dependence of rolling noise is different from that of propulsion noise. Above 40 km/h the sound exposure level (equivalent noise level) increases approximately linearly at 1 dB(A) per 10 km/h average vehicle speed. Below 40 km/h a non-linear relation is found, caused by the fact that a slower vehicle produces noise at a specific receiver position for a longer time than a faster vehicle. From 15 to 40 km/h, the change in noise level is less than 1 dB(A) per 10 km/h; below 15 km/h, the dependence is 1 dB(A) per 5 km/h, increasing with lower speeds. These values are approximately the same for light and heavy motor vehicles. For powered two-wheelers, the dependence is approximately 1 dB(A) per 5 km/h over the entire speed range.

***Speed distribution***

The term “speed distribution” refers to the fact that not all vehicles in each vehicle class drive at the same speed; the distribution of vehicle speeds is a percentage of the vehicle flow driving at a certain speed range, i.e. 40-50 km/h, 50-60 km/h, etc.

If the dependence of the vehicle noise emission on speed were strictly linear, than the distribution of vehicle speeds within the flow would not have an effect on the noise calculation as long as its mean value is correct, but unfortunately this is not the case. However, the requirements for the speed distribution are not very stringent. The resolution of the vehicle speed classes is not very important; speed ranges as wide as 20 km/h (0-20, 20-40, 40-60, etc.) are fine enough. The actual shape of the distribution is more important. A broader speed distribution, with 50%-80% more vehicles in the lower and higher speed ranges instead of in the middle ranges, may have an increase of 0.5 dB(A) on the overall level, even when the average speed is the same.

***Acceleration/deceleration***

The dependence of the noise emission of a road vehicle on acceleration/deceleration is rather complicated. It is non-linear, dependent on the vehicle speed and is different for each vehicle class. Summarizing the results, a maximum deviation of ± 1 dB(A) in the Sound Exposure Level requires an accuracy of:

- 0.3 $m/s^2$ for light motor vehicles and powered two-wheelers at 20 km/h when accelerating, and 0.6 $m/s^2$ when decelerating;
- 0.2 $m/s^2$ for a (medium) heavy motor vehicle at 20 km/h when accelerating, and 0.4 $m/s^2$ when decelerating;
- at 80 km/h, the required accuracy for light motor vehicles is relaxed to 0.6 $m/s^2$ / 2.5 $m/s^2$ when accelerating / decelerating respectively;
- for (medium) heavy vehicles and powered two-wheelers, there is hardly any relaxation of the requirements at higher speeds.

Values of ± 2 m/s$^2$ are hardly ever exceeded in real traffic, with the exception of two-wheelers and sports cars.

***Fleet composition***

Heavy and medium heavy motor vehicles make more noise than light motor vehicles, and may thus dominate the overall noise level even if the number of trucks is low. If the percentage of heavy + medium heavy vehicles is 20% or less, then the exact percentage should be known within ± 5% of the total vehicle flow (i.e. the % of trucks should be within 5 to 10%, or 15 to 20%), in order to have a maximum deviation of 1 dB(A) in the noise emission. If the total percentage of these vehicles is more than 20%, than the requirement relaxes to ± 10% per dB(A).

Within the total number of trucks, the number of medium heavy vehicles (light trucks) should be known with an accuracy of ± 25%.

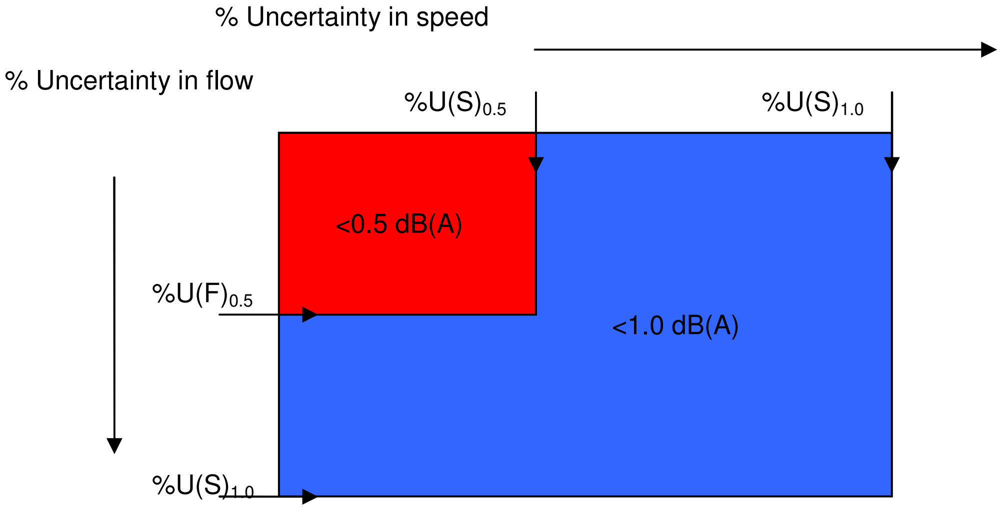
For powered two-wheelers (PTW), there is not enough data yet to correctly estimate their influence on the overall noise emission. So far, the overall levels of powered two-wheelers seem to lie only slightly above those for passenger cars. However, powered two-wheelers may become dominant in certain frequency bands (imagine the typical “humming” noise of mopeds). It is expected that the percentage of PTW in the total flow will be important mainly for inner-city traffic in Southern European countries.

### 2.3.2 Analysis of combined traffic parameters

A first case-study was carried out on the estimation of uncertainty on noise emissions, as a result of combining (expected) imprecisions in the parameters provided by traffic models. This is done by means of Monte-Carlo simulations (MCS), for the macroscopic parameters traffic intensity, traffic speed and traffic composition.

From the MCS analysis it was found that the relative error on mean speed, which is allowed to achieve a defined accuracy in noise emissions (e.g. with standard deviation of 0.5dB(A) or 1.0dB(A)), decreases significantly with vehicle speed. The absolute error stays more or less the same, and is near 10 km/h to achieve 1-dB(A) accuracy. This conclusion could be drawn from both the individual and combined error analysis. It has to be noted that for very low speeds, the required accuracy (on speed data) is expected to be much higher. In addition, accurate speed data is hard to get from traffic models (as is known from literature and experiences), and certainly when using macroscopic models. Therefore, calibration and sensitivity analysis will be necessary in practice. The needed accuracy for traffic intensity is rather insensitive to changes in the mean speed, and to the present traffic intensity itself. The allowed error on speed and traffic intensity also depends on the prevailing % heavy good vehicles. It could be concluded that the accuracy demands depend on the magnitude of the parameters, and simple criteria on individual traffic parameters are therefore often not suited. In Figure 3, an overview is given of the allowed inaccuracies of some traffic parameters to achieve an overall accuracy goal of 0.5 dB(A) and 1 dB(A).

Note that the analysis was based on examination of *hourly sound emission values only*. The effects of uncertainties in propagation and scaling to a long-term annual average would mean in practice that the uncertainty values in the Figure 3 below may actually need to be somewhat tighter.




| Flow | Speed | %HGV | Speed Distribution | $\%U(S)_{0.5}$ | $\%U(F)_{0.5}$ | $\%U(S)_{1.0}$ | $\%U(F)_{1.0}$ |
|---|---|---|---|---|---|---|---|
| 1000 | 105 | 0 | N/A[1] | 5 | 10 | 10 | 22 |
| 1000 | 105 | 20 | Fixed | 5 | 11 | 12 | 22 |
| 1000 | 105 | 20 | Normal | 8 | 8 | 16 | 16 |
| 800 | 75 | 0 | N/A | 6 | 11 | 12 | 22 |
| 800 | 75 | 15 | Fixed | 7 | 11 | 16 | 22 |
| 800 | 75 | 15 | Normal | 10 | 7 | 22 | 16 |
| 500 | 47 | 0 | N/A | 9 | 11 | 20 | 22 |
| 500 | 47 | 9 | Fixed | 12 | 11 | 28 | 22 |
| 500 | 47 | 9 | Normal | 17 | 7 | 34 | 16 |
| 250 | 40 | 0 | N/A | 11 | 11 | 23 | 22 |
| 250 | 40 | 3 | Fixed | 13 | 11 | 31 | 22 |
| 250 | 40 | 3 | Normal | 16 | 7 | 34 | 16 |
| 50 | 32 | 0 | N/A | 16 | 11 | 34 | 22 |
| 50 | 32 | 20 | Fixed | 28 | 11 | 42 | 22 |
| 50 | 32 | 20 | Normal | 32 | 7 | 50 | 16 |

[1] N.A. = not available

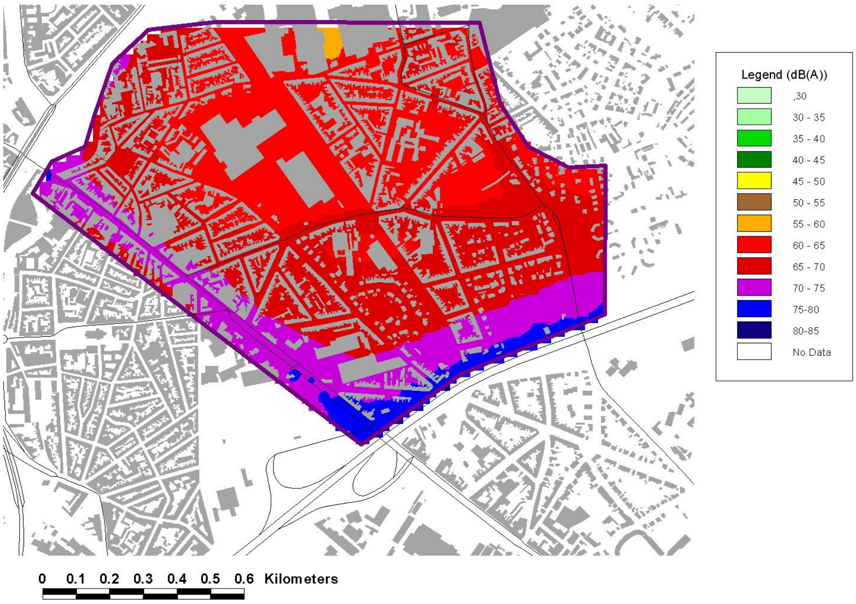
**Figure 3. MCS results – Approximate bounding rectangle regions for % uncertainties in flow and speed in order to achieve an overall standard uncertainty in combined source power levels of 0.5 dB(A) and 1.0 dB(A) respectively.**

For instance, in Figure 3 it can be seen that for a flow of 1000 veh/h, a speed of 105 km/h, a percentage of heavy vehicles of 0% and no speed distribution available, to achieve a maximum uncertainty of 0.5 dB, the maximum errors can be 5% in the speed and 10% in the flow.

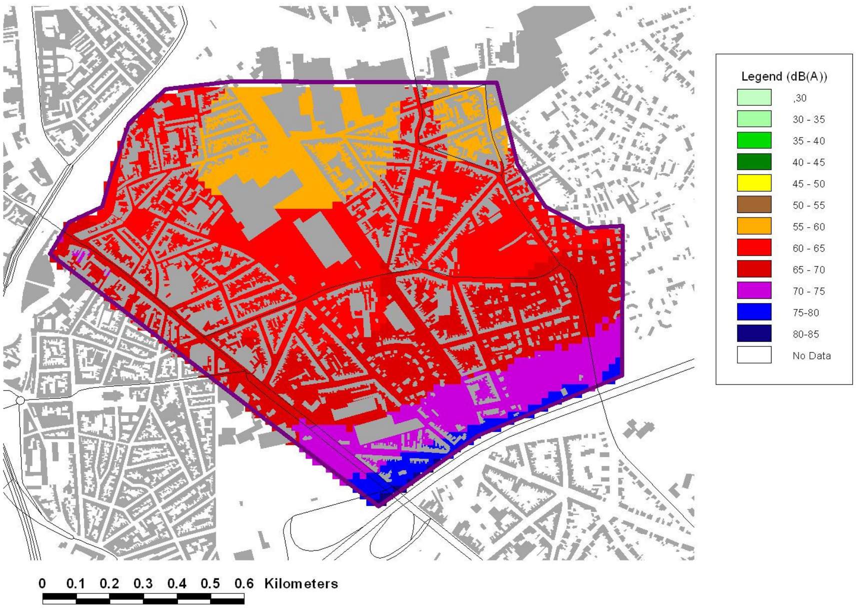
The importance of the microscopic traffic parameters like acceleration/deceleration and vehicle speed distribution data was assessed in a second case-study by making noise maps of a small study-area. For the reference calculations, all available data was passed to the emission module. These calculations were performed in a realistic situation: immission values were calculated, thus including (complex) propagation of sound.

Similarly to the MCS, the speed distribution on the major roads (with higher mean speeds) was found to be important. Differences of up to 3 dB(A), compared to traffic assumed to drive at the speed limit, were found. Neglecting acceleration and deceleration data results (mostly) in an underestimation of the equivalent sound pressure levels, not only near intersections but also at a distance from them. Local errors (underestimates) near intersections in the order of maximum 2-3 dB(A) were observed. When saturation occurs, the errors are present up to large distances from the intersection. More details on this case study can be found in the WP2.3 report [IMAGINE, 2006b].

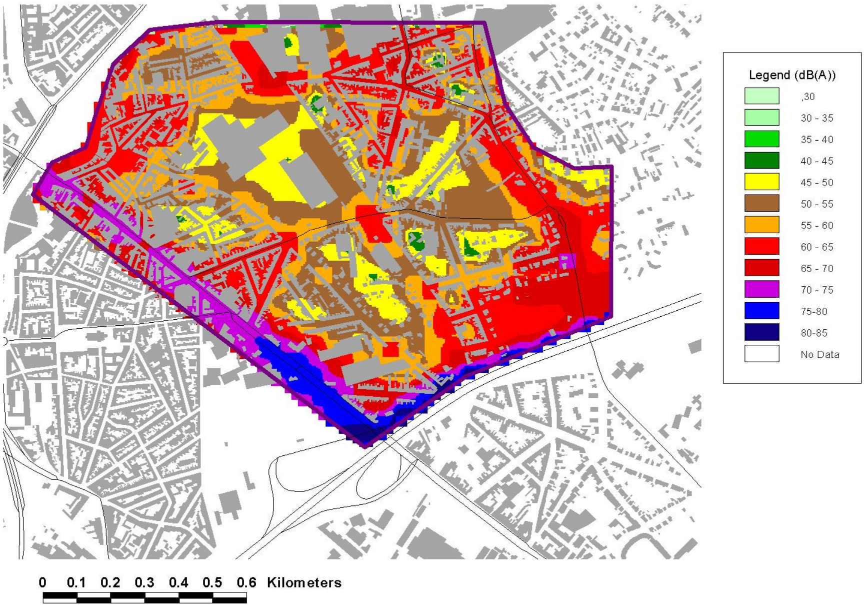
In a third case-study, noise maps for a selected area made for different purposes were compared (Figure 4). Maps a and b are excerpts from regional strategic noise maps. Map b is based on a rough macroscopic traffic model that is tuned to the same traffic counts as the ones used for the interpolation used in map a. The large difference in noise level close to one of the main roads is however due to more accurate accounting for local traffic speed limits in the model. Maps c and d are local maps that include more accurate screening by buildings and more lower-level roads. These detailed maps show an obvious increase in detail at the locations with lower exposure.



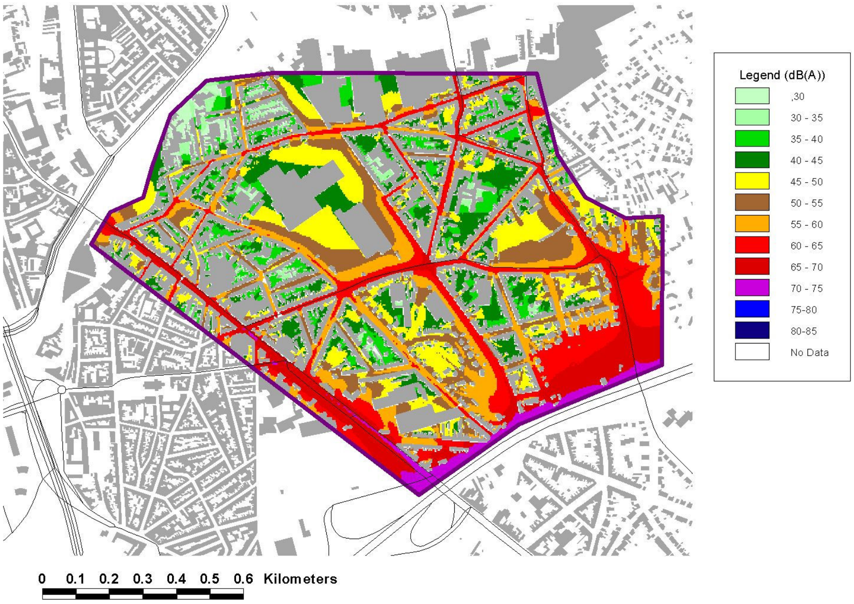

**a. Extract for study-area from the regional noise map, based on interpolated traffic counts.**




**b. Extract for study-area from the regional noise map, based on macroscopic traffic model tuned on the same traffic counts as in map a.**




**c. Extract for study-area from the urban noise map, based on static assignment traffic model.**




**d. Local noise map of study-are, based on micro-simulation traffic model.**

**Figure 4. Noise maps for the study-area Gentbrugge (Belgium), when using different approaches.**

Map c has the same overestimated level near one of the main roads due to incorrect speed modelling in the multimodal macroscopic model. Map d is based on a micro-simulation model that was calibrated and validated in detail on traffic counts. It can be regarded as the reference. From comparing these noise maps, it can be concluded that in current practice, errors at the high exposure side may be expected because of poor modelling of traffic speed. At the lower exposure, neglecting details in the propagation path (screening) and ignoring traffic on lower-level roads are the main cause of error.

#### 2.3.3 Temporal Resolution

The importance of taking care of the variation in time (annual, seasonal, weekly, daily) of some selected traffic parameters for $L_{den}$ calculations was studied. In a first part of this study, the effect of diurnal variations and variations over the week of traffic intensity was studied. The least detailed input dataset, consisting of a single (total) 24-h traffic count, and using the GPG recommendations to distribute intensity over the different periods, lead to a 95 % confidence interval (samples = about 300 different locations on highways in Flanders) of the error on weekly $L_{w,den}$ ranging from -0.6 and +1 dB(A). In the analysis, variations over the different days of the week were disregarded.

For larger integration times, as was clear from a study including 8 types of city roads in Leicester (UK), (extrapolated) annual changes and seasonal changes in traffic intensity seemed of no importance for yearly $L_{den}$ calculations (at the source). City roads like ring-roads and local roads were considered here. Use of weekday profiles alone, as opposed to specific weekday, Friday, Saturday and Sunday profiles also had a relatively minor (sub-decibel) effect on long term parameter values. In this same study, the error induced by neglecting specific flow and speed profiles was investigated as well, and was found to be more important (ranging up to 2 dB(A)), when compared to using assumed flow and speed profiles as defined by the relevant WG-AEN toolkits.

The correlation between typical daily traffic intensity profiles and typical daily propagation conditions for distances larger than 100 m was investigated in a next part of the case study. It could be concluded that using traffic intensity data on a low temporal resolution (e.g. traffic intensities expressed per day) results in average errors on $L_{den}$ values smaller than 1 dB(A), and for $L_{night}$ up to 0.5 dB(A). When looking at specific, daily $L_{den}$ values, errors up to 5 dB(A) are nevertheless possible when neglecting the link between emission and attenuation. It seems that, although the correlation between traffic intensity and the point in time is strong, and although the correlation between attenuation of sound and the point in time is strong, the interaction between both is rather limited when looking at equivalent sound pressure levels over long periods. Traffic intensity data is less demanding as regards temporal resolution than it is for attenuation data.

It could therefore be concluded in general that the importance of temporal resolution decreases when the integration period increases. When looking e.g. at yearly $L_{den}$ values, the influence of temporal resolution as concerns traffic intensity will be limited. On the other hand, variation in speed profiles with time might be more important. If due to saturation of the road, the fluctuation of vehicle speed over the day is large, assuming a constant value over the day can result in errors in $L_{den}$ of several dB(A).

## 2.4 Prioritisation of traffic parameters

When traffic and noise modellers have to discuss what improvements can be made in the traffic modelling process, to obtain the best possible data for the noise model, they will need to weigh costs and benefits. In that respect, it is important to know to what traffic parameters the closest attention should be paid. From the information in this chapter, the following list can be derived that lists the traffic parameters by importance for the noise modelling process:

1. vehicle speeds & traffic composition;
2. vehicle flows;
3. acceleration/deceleration;
4. speed distributions
5. (data regarding the above parameters on) low flow roads.

This list[3] is based on the sensitivity of the noise model towards each of these parameters: the largest inaccuracies will be introduced by insufficient data in the top categories of this list. This does not mean, however, that large amounts of budget should always be spent on acquiring 100% accurate and representative vehicle speeds. If no vehicle flow data are available, it may be an option to estimate the vehicle speeds by simply using the speed limits at the location, and spend the main budget on gathering vehicle flow data for the separate vehicle classes.

To ease these complicated decisions, the guidelines in Chapters 6 and 7 have been developed. They provide an estimate of the cost/benefits of different measures that can be taken to improve each of the parameters above. Combining the priority rating above with the guidelines should enable a profound decision on where to start an improvement of the model.

[3] The road surface type (not discussed in this report) is an important variable in the road noise source model. In the list above, it would probably be ranked between the numbers one and two (and thus accuracy in the road surface type may be more important than accuracy in flows).

# 3 Introduction to traffic models

The modelling of vehicular road noise requires detailed data of traffic. Volumes and speeds per road section are needed to calculate noise emissions. Information about speed distributions and accelerations can also be important. Furthermore, information on fleet composition is needed. Much of the traffic data needed can be delivered by traffic models.

This section introduces traffic models and discusses the ability to use their output for noise modelling. Traffic modelling consists of the description of the movements of people and goods in a region. For that reason, the decision processes of travellers are reconstructed in detail within such models.

The development of traffic models has a long history with roots in different fields. Techniques and methods from geography, economics, physics and operations research are used to describe the travel behaviour and the resulting traffic pattern.

Traffic modelling has helped policy makers in their planning decisions. Traffic models were originally built to support decisions on new transport infrastructure, but the applications have broadened to, for instance, the use for environmental policies like noise.

To simplify the different approaches and developments, two main components in traffic models are distinguished.

- **Traffic demand models** focus on the travel patterns in a region. Main questions here are to declare why, where and how people travel. The demand model results in a table with spatial distribution of trips.
- **Traffic network models** focus on the movement of vehicles on roads. The output of the demand models are used here to calculate flows and speeds for traffic flows in networks.

This chapter clarifies both types of models and explains their interaction. A first section introduces the traffic demand models. Subsequently, the different approaches to traffic network models are discussed. A section on the accuracy of their results and the possibility to use them for noise modelling close this chapter.

## 3.1 Traffic demand models

***Background***

Traffic demand models focus on the travel patterns in a region. The result of the demand model can be described in an origin – destination matrix (OD table), representing the number of people that want to travel during a certain period between the origin and destination zones using a certain mode of transport.

Demand models try to describe the underlying decision processes of travellers and transport firms. The traditional approach of constructing an OD table comprises the first three steps of the classical four step transport model, as explained below.

***Modelling technique***
The classical three demand steps correspond to three choices that every traveller makes :
- Will I make a trip?
- Where will I travel to?
- What mode will I use?

These choices are simulated for all people in the study area during the study period. Usually a differentiation is made between classes of people. This differentiation can be made on different levels, resulting in a hierarchical classification.
In most cases, the first level of differentiation is made on the basis of travel purpose: are people making trips from home to work, from home to school, for business reasons, for recreational purposes? Sometimes the classification is further subdivided, for example on the basis of car availability. Other ways of subdividing are possible, for example on the basis of income.

The first choice (*Will I make a trip?*) is modelled in the **generation** step. This step results in an overview of the number of starting trips (productions) and arriving trips (attractions) per zone. Productions and attractions are determined on the basis of socio-economic data, travel surveys and activity parameters.

The second **distribution** step links the departing travellers to the calculated destinations (*Where will I travel to?*). Linking origins to destinations is modelled on the basis of trip distribution functions, which are observed relations between trip resistance and the number of trips.
Trip resistance is a general quantity taking into account all variables relevant for the distribution process, such as travel distance, travel time, toll costs, etc.. Since a number of these variables (primarily travel times) are dependent on traffic conditions, the distribution process will also be dependent on traffic conditions on the network. Furthermore, the distribution process also depends on the available travel modes. Therefore this second step is mostly combined with the third **modal split** step (*What mode will I use?*). In that case separate trip distribution functions are needed for each travel mode.

The result of these three steps is a number of tables containing the number of trips between each zone, one table for each purpose and mode. These OD tables are a static representation of travel demand for the study period.

As mentioned in step 2 (distribution), traffic conditions (in particular travel times) are quite important for the transport demand modelling. Therefore the search for a transport equilibrium needs the iterative run of both traffic demand models as well as traffic network models.

***Possible improvements***
This traditional demand modelling framework seems quite pragmatic but has some drawbacks. For instance modelling the impact of e.g. time-of-day and price measures, will lead to difficulties. Therefore a more complete and coherent framework from general econometric modelling can be used. Using mathematical techniques (e.g. logit models, see [Ben-Akiva, 1985],[McFadden, 1974]) a more disaggregated and stochastic demand model was developed. This framework will possibly be extended based on extensive research in the area of ‘activity based modelling’ [McNally, 2000]. Trip demand is then expected to be modelled as a derivative of spatial and temporal activity patterns.

At the moment methodologies are developed to model time-of-day choices (e.g. the choice between travelling during peak or off-peak period). Knowledge of the evolution of demand over time becomes increasingly important because dynamic traffic network models need this input. The activity based approach seems promising in delivering more supported dynamic OD tables. However, the accuracy of traffic demand will probably remain difficult. Calibration of OD patterns needs a large amount of data. Furthermore, (in most cases) an OD table cannot be observed, only traffic flows on individual network links.

Other challenges exist for the modelling of freight demand. Freight transport is only a small part of freight logistics. Similar to activity based models, the complete modelling of the logistic processes can result in better OD tables for freight. It should be noted that the lack of data is here even more critical. Obtaining data is very difficult, largely because transport firms are reluctant to disclose their logistic processes.

***Output of demand models***

The origin – destination tables represent the output of demand models. The typical use of demand models results in demand information per zone (areas between the size of 0.5 km² for a model of a town and 1000 km² for a model of Europe) and per time period. The simulated time period is typically 1 hour for a peak model, but dynamic evolutions occur (for example consisting of 5 minute periods).

***Modelling of measures***

All kind of measures can be modelled. It should be noted that time costs also come into the picture. Traditional measures comprise changes in transport supply (new infrastructure, changes in public transport, etc.). Interest is growing in the prediction of the impact of pricing measures and changes in the driving forces of transport demand (e.g. changes in the spatial activity system).

## 3.2 Traffic Network Models

Traffic network models describe the flow (intensity) and speed of vehicles in a road network. The output of traffic demand models is traditionally used to feed these models. Four types of traffic network models are distinguished. The proposed classification is based on the way the different models deal with time and space. The four categories are:

- Static assignment models
- Dynamic assignment models
- Continuum models
- Micro simulation models

This classification can also be seen as a clustering of historical paths in traffic model development. The classification is consequently used within all IMAGINE reports on road traffic noise. The remainder of this section contains a short description of each type of traffic model. More background material on the different approaches can be found in the IMAGINE WP 2.2 report [IMAGINE, 2005].

### 3.2.1 Static assignment models

***Background***

Static assignment is the classic approach in traffic modelling: the first transport models developed were of this type. In the sixties, when computers appeared on the scene, it became possible to calculate flows on networks. The rather simple modelling technique and limited data needs made static modelling the logical first step.

***Modelling technique***

Static traffic assignment [Sheffi, 1985] is the process of allocating trip matrices (*origin-destination matrices or OD-matrices*) to their routes (paths) in the network, resulting in flows on links. The assignment process is typically used to produce a number of indicators, not just flows. The main objectives of traffic assignment are:

- to obtain good aggregate network measures (e.g. total motorway flows)
- to estimate zone-to-zone travel costs (time)
- to obtain reasonable link flows and to identify heavily congested links
- to estimate the routes used between each origin-destination pair
- to analyse which origin-destination pairs use a particular link or route

Static assignment methods are generally hour based: the origin-destination matrix contains for instance the trips of a peak hour. The capacities of the road network are expressed as number of vehicles per hour. As a result, the flows the assignment estimates are average flows per hour. With a static assignment, it is therefore not possible to get an insight on the development of a peak period. Consequently, these types of assignment are usually applied in long term policy studies.

The basic assumption in assignment is that travellers choose the routes that offer the lowest perceived individual costs. This cost can be divided in travel time and monetary travel costs.

A problem in most static model applications is that the modelling of different vehicle classes is handled too simply for noise modelling. For instance, results for trucks and motorcycles (which are important for noise issues) are often not distinguishable. However, the static modelling technique is suitable for different vehicle types (using the so-called multi user class approach), but this generally requires more input data.

***Output of static assignment models***

The following output is generated by a static assignment model at network level:

- flows on links/routes
- speeds on links (although in practice, static models are very rarely calibrated on speeds, which means that the predicted speeds may not be reliable enough to be used)

All vehicles on a link are assumed to have generally the same speed, so a speed distribution cannot be derived. The acceleration of vehicles is not modelled either.

***Modelling of measures***

Network measures, such as a change in capacity or speed of a road, or a new road are easy to bring into the static assignment model. More dynamic measures, like dynamic traffic management or variable message signs are not easily included. For pricing measures, assignments with different user classes are available.

Measures that influence the transport demand, like measures stimulating public transport or spatial planning measures, have to be input in a transport demand model, which generates the origin-destination matrix. This matrix is then input for the assignment.

The relatively simple nature of static assignment modelling, introduces at the same time a possible pitfall. Due to the aggregation level of results and the averaging of indicators, careful attention must be paid to the interpretation of the results and the limitations of static models and the way they are calibrated. Otherwise, erroneous conclusions and a false sense of accuracy are the result.

***Expected developments***

Unlike in the past, static assignment will not automatically be the first model type where new developments are tested and implemented. Static and dynamic models are expected to grow towards each other.

### 3.2.2 Dynamic assignment models

***Background***

Dynamic traffic assignment (DTA) models were and are developed as an improvement of the ‘traditional’ static assignment. DTA models can be used to generate forecasts of traffic that illustrate how traffic flows and congestion levels vary over time. Such models can therefore better represent actual traffic flows and can evaluate in more detail policy options aimed at a more efficient use of the current road network. DTA models can also be used for prediction and control purposes (e.g. by traffic operators) and for on-line control. In combination with demand and time-of-day models, DTA models are an alternative for static assignment models in the future. At this moment, DTA models are not very common for practical applications, but they are receiving more and more interest. In general, DTA models use time periods of a couple of hours, mostly including one peak period. But simulations of 24-hour periods are also possible (although this will result in long run times). DTA models focus on the performance over time of the network under study.

***Modelling technique***

Resembling static traffic assignment, dynamic traffic assignment is the process of allocating *time-varying* trip matrices to their routes (paths) in the network, resulting in *time-varying* flows on links. The trip matrices are normally defined in trips per hour or trips per quarter of an hour. For each hour (or quarter) of the total time period a different trip matrix is fed into the DTA model to model a time-varying demand. DTA in general can produce the same figures as the static assignment does, but with DTA more insight is gained into the dynamics of these figures. In general, DTA models can be divided into two separate sub-models: a dynamic network loading model and a route choice model.

The dynamic network loading (DNL) model defines the way in which traffic moves along links in the network. DTA models can differ in the way in which the traffic is transported over the network, by using different DNL models. These models can, for instance, make use of speed-density functions, define the in- and outflow rates of vehicles on a link using node modelling or make use of continuum or micro-simulation models. The most important issue here – and a major distinction with respect to static traffic assignment models - is that these DNL models take into account not only the current, but also the historical development of the traffic on the link. Another important remark is that many DTA models require that the time step has to be smaller than the shortest free flow travel time over a link in the network. Otherwise, traffic can traverse over the complete link under consideration when this condition does not hold. DTA models can also be distinguished with respect to the way in which the routing of the traffic is modelled. This can be done by using a fixed route set containing all used routes between the different OD pairs. For each route, the flow propagation between an OD pair is defined. A second method uses split fractions at nodes. With the first method, the routes used between any OD-pair can be easily tracked. With the latter method, this is not always possible.

Within the route choice model, the type of assignment that is carried out is defined. Dynamic versions have been developed for the different static assignment types (all-or-nothing, user-equilibrium or stochastic assignment). Without departure time choice, these assignment types basically do the same as in the static case, only now routes are re-assigned on a dynamic basis, e.g. every 15 minutes. For the user-equilibrium and stochastic assignments, multiple iterations are required. During each iteration, all traffic for the complete period under study is assigned. Once all traffic has been assigned, and all vehicles have reached their destinations, the next iteration can start.

In the (near) future, DTA models will include realistic congestion spill-back modelling. Spill back means that traffic queues build up in the network, eventually blocking routes of traffic that was not planning to pass the location of the cause of the queue. Spill back modelling requires an accurate geometric description of nodes to be able to realistically model spill back effects.

***DTA models combined with simulation***

There are also DTA models that combine an iterative traffic assignment algorithm with a traffic simulation model. It can be expected that both continuum and micro-simulation models will be extended with accurate route choice models. Joining DTA and simulation models will certainly lead to improved traffic flow description.

***Output of dynamic assignment models***

The following output is generated by a dynamic traffic assignment model at network level:

- time-varying route flow proportions;
- time-varying travel times, flows and speeds on links.

All indicators can be generated for specific user classes, when a multi user class DTA model is used.

When compared to static assignment, DTA models give a better representation of the fluctuations in traffic flows and speeds, which improves noise calculations. However, data on acceleration and speed distributions are not generated by DTA models. The models do provide a (time) series of speeds for each link, but these are all average speeds on the complete link (for each time step). Peaks in speed are therefore not modelled.

Another advantage of DTA models over static assignment is that DTA models more accurately predict the location of a queue. Static assignment predicts the queue in the bottleneck, whereas DTA models the queue upstream of the bottleneck, which is more realistically, and may be important in the noise modelling application.

***Modelling of measures***

In addition to what can be modelled in static models, DTA models can model dynamic traffic management measures (infrastructure & pricing, spatial planning). Also, it is possible to model the effects of shifts in departure times. Measures influencing traffic flow characteristics cannot be modelled. DTA models can also be used in on-line applications, e.g. for travel time prediction and to support Dynamic Traffic Management.

### 3.2.3 Continuum models

***Background***

The efforts of physicists in describing road traffic resulted in continuum traffic models. The first attempts in transfer fluidum modelling techniques were done by well-known personalities from physics research [Lighthill, 1955] [Prigogine, 1971]. These techniques have been improved further and extensions towards typical road based physics are developed. The evolution in model development has not yet led to numerous commercial software packages. Because of that, there is only a limited use of this type of models in practice. Nevertheless, a lot of traffic research is done within this area and these efforts will certainly lead to renewed attention for this type of models, in theoretical as well as in practical applications.

***Modelling technique***

Within a continuum model, vehicles are not treated as separate entities. The discrete nature of traffic is idealized to a homogeneous fluidum. Within this continuum approach traffic is described using typical variables from physics: density, intensity (also called the flow or flux) and the average speed. Within the model, vehicles and their drivers are represented by identical fluid particles in a tube.
The basic principle of conservation of mass is translated as conservation of vehicles on a road. Pressure is the driving force for the particles in gasses and fluids. This mechanism is substituted for traffic. Particles in the traffic stream (vehicle – driver entity) have some kind of intelligence. The behaviour of vehicles on a road is usually described in an empirical driving behaviour function. This function is then used instead of the pressure equation to have a consistent model of traffic on a crowded road. The easiest assumption of such an empirical relation that reflects driving behaviour on a road is the 'fundamental diagram of traffic flow'

The fluidum model is a set of mathematical equations. Sometimes this can be solved analytically, but in practice a numerical scheme is used. This means that a link is divided up in cells with length varying between 10 and 500 meter and that traffic conditions are calculated in time steps of 0.5 to 10 seconds. This results in a detailed description of traffic conditions in a space time lattice. The traffic density, the flow and the average speed are then known along the road at each time step.

Continuum models traditionally focus on long crowded roads. The extension of continuum models to road networks needs the formulation of node rules. Nodes have no physical length and act as flow exchange locations between links. By developing node definitions the model can describe traffic at junctions, off-ramps, on-ramps and traffic lights.

Further extensions focus on typical traffic properties. Traffic is not a real homogeneous medium. Therefore multiclass models are developed where differences in vehicle properties (e.g. long trucks versus small cars) and driving behaviour (e.g. aggressive versus slow acceleration driving behaviour) are developed. Within multilane models, the lanes are modelled as various parallel tubes with exchange possibilities. Other assumptions on empirical traffic behaviour lead to complex higher order models (where traffic pressure is defined) or kinetic models (where overtaking probabilities are calculated).

***Output of continuum models***
All traffic variables calculated can be listed and aggregated. Also statistics and parameters based on these core variables can be calculated and reported. Based on the detailed flow pattern an average flow on a link during a certain period can be calculated.
Since no commercial packages exist, the use of this type of models is rather limited. Therefore, it is difficult to say something about the 'standard' output of continuum modelling packages.

***Modelling measures in continuum models***
Continuum models describe traffic operations in detail. Therefore they are specialised in measures that influence traffic flow characteristics. Measures that do not influence traffic demand and route choice are the most likely to be modelled. Therefore continuum models are mostly used for the evaluation of short term measures (e.g. impact of removing incidents, ITS measures, etc.) or in on-line control systems (predicting travel times, as input in control algorithms of traffic signals).

***Continuum models in practice***
Until now, this type of models was rarely implemented in practice. Commercial continuum software packages are rare (examples are Netcell, Metanet, etc.) and or used for (real-time) dynamic traffic management. We can see growing interest in the development of fast continuum models. In particular, their use as dynamic network loading model in the framework of dynamic assignment models seems near. This will result in more software packages and application within traffic control and traffic operations.

### 3.2.4 Micro-simulation models

***Description***
Traffic micro-simulation attempts to model the progression of individual vehicles through a road network during a specified simulation time period. A micro-simulation model breaks the overall simulation period down into a large number of discrete time steps, and within each time step uses a number of individual algorithms to generate decisions for all vehicles within the network area. The decisions made are then used to update vehicle position, speed and acceleration information. The methodology used for the simulation process in micro-models falls into two main categories:

- Models in which the available road space and vehicles are treated as fundamentally separate units, with road space viewed as a continuum, and:
- Cellular Automaton (CA) models, where road space is divided into a number of discrete segments, each approximating a vehicle length, which may be occupied or un-occupied at any given time.

The ability to model individual vehicles gives micro-simulation models a number of advantages over traditional, static models. Micro-simulation is typically used to study the effects of short-term traffic management schemes, signal control policies or public transport priority schemes. With care and careful calibration, such models may be used to accurately assess the effects of heavy traffic levels and urban congestion. Advanced models may be used to study the impacts of incidents (e.g. shockwave propagation after traffic disruption), lane changing or weaving behaviour, Intelligent Transport Systems (ITS), dynamic route guidance systems or in-vehicle systems such as Intelligent Speed Adaptation (ISA).

On a typical office PC, at the time of writing, the geographical scale micro-simulation models can practically handle may range from small regions, spanning several junctions, to entire city areas spanning several hundred junctions and several thousand vehicles at any given time. A number of highly-parallel micro-simulation models has also been developed, capable of modelling entire regions within a country or state on multi-processor systems. In order to reduce running costs, it is a general requirement for the simulation package to run at greater than real-time speeds.

A given micro-simulation package may contain a vast array of sub-modules, depending on the exact application to which the package is applied. However, a number of core components in any micro-simulation model may usually be identified:

- The *network editor*: provides for the development and maintenance of a representation of the traffic network under consideration
- The *traffic-signals* database stores signal timing settings and controlled traffic streams for individual junctions in the network representation.
- The *vehicle/driver* database holds information on vehicle characteristics and behavioural parameters.
- The *simulation* module is the heart of any traffic micro-simulation model. When running the simulation module iterates through the simulation period using discrete time steps to model the progression of vehicles.
- The *output or visualisation* module provides tools to both visualise and display vehicle movements during simulation (the often impressive birds-eye view of traffic) and to collate and output vehicle or network performance parameters

A typical micro-simulation model contains a number of sub-components that may be run within a given time step. These include:

- The *vehicle generation* algorithm injects individual vehicle units into the network.
- The *car following* algorithm defines speed, acceleration or deceleration of a following vehicle as a function of the physical distance and velocity difference between the leader and follower.
- The *signal behaviour* algorithm governs how leading and following vehicles interact with traffic signals.
- The *gap acceptance* algorithm governs how and when vehicles will enter an opposed traffic stream.
- The *lane changing* algorithm governs a vehicles' desire to move across lanes. This may be triggered by a variety of stimuli, such as a following vehicle moving due to a slower leading vehicle or moving to the correct lane for a particular turning movement.
- The *vehicle update* algorithm that applies the results of any decisions to vehicles to update their position.

***Outputs for traffic micro-simulation:***

Micro-simulation models may produce output on a variety of levels. A typical micro-simulation may provide output at the microscopic level (individual vehicles and their driving paths), mesoscopic level (average values at link levels) or macroscopic level (aggregated values for the complete studied network).

The ability to produce vehicle speed information directly at the microscopic level (per vehicle, per time step) is of primary interest to noise modelling. It allows the vehicle sound power levels to be calculated in greater spatial and temporal detail than for other types of traffic model. However, the broad scope and level of detail of such models means that a variety of approaches may exist for the precise methodology used to aggregate emissions levels and assign them to the road space. Storing micro-scale parameters will also results in huge data management efforts.

## 3.3 Reliability of the traffic data provided by traffic models

Traffic modelling is not based on fundamental physical laws. The modelling of traffic involves the description of numerous decisions of travellers. Thus, the nature of traffic brings along unreliability in the output.

Also the current practice can cause unreliability in the traffic model results needed for noise calculations. Current applications of traffic models generally focus on transport related objectives and problems, like accessibility of areas and levels of congestion. This means that the set-up and application of these models is focused on specific items within the policy framework of transport (e.g. capacity, travel times). Using output of these models for other purposes will introduce additional uncertainties and difficulties, because the models are not calibrated for this use, or do not contain the right parameters, e.g. like certain times of day.

Within the state of the practice in traffic models, the main focus is on:

- **Flows on links**
  The main focus of traffic models is on describing the flow (intensity, flux) on some of all links rduring the period under study.
- **Travel times / speeds**
  Traffic engineers focus on travel times over links or even travel times aggregated over a part on the network. They seldom focus on the reliability of average speeds on certain locations.
- **Peak hour**
  Transportation policies traditionally focus on peak hours. Off-peak and night periods are traditionally not modelled in detail.
- **Main roads**
  Traffic models are traditionally focused on main roads, because of their importance in the traffic network.
- **Typical day**
  A traffic model focuses on modelling a ‘typical day’. Generally, no strict definition of the considered day is proposed. Mostly a quite ‘busy day’ is implicitly assumed where holidays or bad weather conditions do not influence traffic operations.
- **Focus on measures**
  A traffic model is in general developed to evaluate the impact of a policy. Model results with and without the proposed set of measures are compared in this case. The model is not necessarily calibrated on the absolute values of model results, but on the relative impact of measures.
- **Less validation**
  Validation of traffic models using independent data occurs rarely.

All of the above means that using traffic data from a traffic model for noise models will necessarily involve additional quality checks on the traffic parameters which are important for noise modelling and which the traffic model should ideally be optimised for. These parameters are speeds, traffic composition and flows.

There are acceptability guidelines for flows (see section 2.2.1 of the IMAGINE WP2.3 report [IMAGINE, 2006b] and section 3.3 of the IMAGINE WP2.4 report [IMAGINE, 2006a]), which describe the maximum difference between flows resulting from the traffic model and flows from traffic counts. Using these acceptability guidelines should ensure that flows will meet the accuracy standards of the noise model. This will, however, not guarantee the accuracy of other traffic parameters.

For speeds, the same section in the report mentioned above contains a acceptability guideline. However, this guideline focuses on the accuracy of calculated journey times, which gives little indication of the accuracy of link speeds.

As for traffic composition, while micro-simulation models (nearly) always offer the possibility to model several vehicle categories, this is not necessarily the case for macroscopic models. If the transport demand and traffic assignment models do not (or only partly) distinguish between vehicle categories, this will inevitably cause unreliability in the traffic model results that are used in the noise model. The available acceptability guidelines for flows and speeds (travel times) can also be applied per vehicle category (if data is available), but this is not common yet.

The next section describes how the results of traffic models can be used for noise modelling.

# 4 The use of traffic models for noise mapping and noise action planning

## 4.1 Steps in the traffic modelling process

### 4.1.1 Introduction

The provision of traffic data in a form suitable for quality noise modelling is assumed to be the basic aim of traffic modelling in this context. Ideally, the whole process would be driven by the question *"what do we require in order to produce the highest possible quality noise mapping?"*

Answering this question would involve the creation of new traffic models and data collection methodologies specifically for that purpose – and would be prohibitively expensive. Logistical and budgetary considerations force compromises in modelling. At all levels, consideration should be given to the effects of these compromises on the accuracy of mapping.

It is expected that high quality mapping will depend on successful communication between traffic engineering practitioners and acousticians. Traffic engineers should be aware of the demands of the acousticians –which may be high given the potential detail requirements of the HARMONOISE methodology– and acousticians should be aware of the capabilities and limitations of traffic models (and monitoring systems).

The following guidance text is intended as informative to both parties. It attempts to summarise the relevant points of discussion, whilst indicating possible documentation requirements and illustrating methodological approaches.

### 4.1.2 Initial Considerations – defining scope

For a given project, the precise realisation of the stated aim (of providing traffic data for noise calculations) will vary depending on:

- The fundamental purpose (and geographic scope) of the mapping exercise, i.e.:
  - Strategic noise mapping, or;
  - Localised action planning;
- The nature of the road network under consideration, i.e.:
  - Primary routes (main roads) with mainly free flow traffic, or;
  - Roads within an agglomeration possibly subject to extensive congestion;

- The temporal scope:
  - Requirement for long-term annual average $L_{DEN}$ calculation;
  - Requirement for long-term annual average $L_{night}$ calculation;
  - Other subsidiary parameters under consideration (e.g. # peaks overnight etc.);
- Parameter and desired accuracy:
  - Flow, speed and 3-classification fleet composition (HARMONOISE Classes 1, 2, 3) at a minimum;
  - Use of Multi-User Class (MUC) assignments;
  - Requirement for further parameters (acceleration, queue lengths etc.);

- (For action planning) the types of scenarios to be modelled;
- The availability of suitable input data sources, e.g.:
  - Existing digital mapping data;
  - Existing survey or census data;
  - Existing traffic information from authorities or other parties;
  - Existing traffic models and/or standard practices;
  - Coverage of traffic detector networks to provide historic and/or current data;
  - Possibility to deploy new traffic detector systems;
- Other data issues:
  - Need for post-processing of traffic data to require spatial/temporal levels;
  - Compatibility with existing GIS or acoustic modelling software.

All of the above will influence:

- The type of traffic model selected (i.e. macroscopic versus microscopic);
- The necessary calibration and validation data;
- The final modelling outputs.

It is recognised that the final traffic data presented for use within the noise model may be derived from the use of multiple data sources and/or models. In some cases, it may be possible to use measurements for the noise map (e.g. when considering main roads that have been equipped with permanent measuring stations on all relevant sections). However, it is assumed that, even with complete detector coverage and perfect historic data, a traffic model will always be necessary in order to:

- Forecast future traffic patterns (i.e. to the end of the mapping period considered);
- Assess the implementation of action plans.

### 4.1.3 Choice of model

There are several possible situations that traffic and noise modellers may find themselves in:

1. A traffic model is available, and is (nearly) perfect.
2. A traffic model is available, but has deficiencies. In that case, two approaches are possible:
   a. devise strategies to get around the deficiencies of the model (by assuming values when they cannot be calculated);
   b. solve the deficiencies (the model is adapted to deal with the specific questions of noise mapping and noise action planning).
3. No traffic model is available. Solutions to this problem are:
   a. to build or purchase a model;
   b. to estimate or measure (not calculate with a model) the indicators needed (traffic volumes, speeds, etc.).

*Situation 1* can be considered to be non-existent. In this report, the focus is on *situation 2*. Guidelines are presented to either solve the model deficiencies or to get around them.

For *situation 3b*, the reader is referred to the (forthcoming) deliverables of work package 3 of the IMAGINE project (Monitoring and Measurement methods) and the Good Practice Guide [WG-AEN, 2006].

Regarding *situation 3a and situation 2*: there is no harmonised European traffic model. Several traffic model types (commercial packages and others) are used throughout Europe, most of which can be used to produce useful input for strategic noise mapping for main roads. The IMAGINE WP2.2 report [IMAGINE, 2005] discusses the strengths and weaknesses of four types of traffic models (static assignment, dynamic assignment, continuum models and micro-simulation). In the guidelines in this report, a distinction is made between the following model types that the selection process will probably be between[4]:

- Macroscopic models (static and dynamic assignment) – providing flows and a measure of speed at the link level;
- Microscopic models – modelling at the individual vehicle level.

The acoustician should be aware of the former's inability to provide the highest level of detail of data to the HARMONOISE source model, whilst the latter are stochastic in nature and will require statistical analysis of output data to ensure it is representative.

Macroscopic models may be the primary choice for strategic noise mapping, and for action planning involving broad policy changes (e.g. HGV bans, global reductions in speed). Microscopic models may be a better choice for complex urban/intersection modelling, or assessment of action plans involving subtle policy instruments.

From the above, the possibility exists that the assessment of an action plan may involve the use of a different model from that used to produce a strategic map. It is not suitable to assess differences between maps produced using different models as this may obscure the true nature of changes. Rather, it is necessary to model *before* and *after* scenarios for action planning within a consistent modelling framework.

In the end, the choice for a certain model type will also depend on the model available for the area under study, available data (or additional data collection possibilities) to fill and calibrate the model and budget constraints. It is important to report the choices and compromises made in the traffic modelling process; Annex 2 provides a checklist that can be used for that purpose.

*Other sources about the choice of a suitable traffic model*
Section 5.2 (Recommendations) of the IMAGINE WP2.3 report [IMAGINE, 2006b] gives some additional information about what aspects of traffic models users should consider in the context of noise mapping and noise action planning. National, regional and local authorities may have specific guidelines for the choice of traffic model type. Another useful publication to consult is the Traffic Analysis Toolbox Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools [FHWA, 2004], published by the Federal Highway Administration of the US Department of Transportation, available at http://www.ops.fhwa.dot.gov/trafficanalysistools/index.htm.

### 4.1.4 Data Collection Considerations

Traffic data may be provided from a wide variety of sources. Initial contacts with regional or national authorities may yield an initial data set, comprising default parameter values. Local traffic management or planning authorities may be able to provide additional or more specific data. Third party commercial organisations may be able to provide further services and data.

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[4] There are very few continuum (or gas-kinetic) models yet, and it is not expected that they will be used much in noise mapping and noise action planning in the coming years. Therefore, no specific guidelines will be given for this type of models, but it is likely that the guidelines for micro-simulation will apply.

Additional traffic data may be collected using either in-situ detectors (fixed locations), or from in-vehicle monitoring (mobile measurements). Some degree of post-processing of detector information will be required to provide a form suitable for model calibration/validation.

Traffic Management Centres (TMC) or Urban Traffic Control (UTC) centres may have extensive information. Intersection and road geometry may be obtained from relevant agencies via digital mapping data, CAD drawings or aerial photography. Traffic signals information may be obtained from relevant authorities or operators.

### 4.1.5 Coding considerations

If a new traffic model is to be built it must be remembered that network coding is a major task. Even updating an existing model may require extensive network changes.

Traffic model coding entails:

- Coding physical geometry;
- Coding traffic signals (where necessary);
- Coding demand levels.

Network coding entails:

- Set up of coding templates and methodologies to standardise and expedite the process;
- Acquisition and import of suitable aerial photography, or digital data to the traffic model;
- Rough coding of node positions;
- Rough coding of links between nodes;
- Coding of link parameters (e.g. free flow speeds, capacities, speed-flow curves etc.);
- Coding of intersection attributes (e.g. control types, saturation flows, available turns etc.);
- Coding of sinks and sources nodes or zones;
- Coding appropriate origin-destination matrices;
- Review and refinement of model parameters.

Micro-simulation models will also require:

- Coding of vehicle types (e.g. length, acceleration etc.);
- Choice of simulation parameters (e.g. driver behaviour, headway models etc.).

### 4.1.6 Spatial Considerations

Any model will be based on a topological representation of a real world network. Consideration should therefore be given to:

- The coding of the network – traffic models typically contain a unique *link* reference based on connection to *nodes* – termed an *A-B reference*. If the traffic network cannot be ported directly into a noise mapping application, or another universal identifier (e.g. unique ID from a central database system) is not available, then the A-B reference may be used to link between the traffic application and a noise modelling application.
- The extent of the network – it is usually necessary to model somewhat beyond the required extents of noise mapping, in order to include all possible effects within a model, i.e. the core area required for mapping will be surrounded by a *buffer zone*;

- The level-of-detail within the network – how much information may be extracted regarding specific features such as short link sections, road intersections etc. that may be of relevance to noise mapping;
- The extent of model calibration/validation – a traffic model may produce better calibration or validation results in particular sub-sections of the overall network, whilst other areas may be less well behaved. Care should be exercised if a large network is cordoned to produce results for more localised areas;
- The treatment of gradients within the model, if they are treated at all.

#### 4.1.7 Model Verification, Calibration and Validation

Any traffic model should be verified, calibrated and validated, before its output is declared fit-for-purpose. These terms are defined as:

- *Verification:* Checking the functionality of the model – i.e. the model has been built *right*;
- *Calibration:* Alteration of parameters within the model to reflect a given scenario;
- *Validation:* An independent check of the performance of a calibrated model.

Each stage should be documented and auditable, though the acoustician will be primarily concerned with validated outputs. It is recognised that individual member states may have existing guidelines on the application, calibration and validation of traffic models – these may be more or less applicable to the overall process. Guidance on the successful application of micro-simulation models is also plentiful. The advice of software vendors, and model user-support groups, may provide further ideas or recommendations.

Calibration and validation require on-street data collection. Two different data sets are needed, i.e. calibration does not use the same data as validation. The methodology used to calibrate/validate a model should be clearly stated. The process may be non-linear, involving the minimisation of least-squares errors.

Micro-simulation models have different calibration and validation data requirements from macroscopic models. Macroscopic models are calibrated and validated mainly by using flows and journey times for specific routes. Additional parameters may be collected for micro-simulation models.

#### 4.1.8 Temporal Considerations

For strategic noise mapping the measure required under the END is a *long-term annual average* measure. This implies that the traffic data used should be representative of a period spanning 'all the day periods of a year'.

Due to the expensive and time consuming nature of survey work a particular traffic model may be considered truly representative of only:

- A limited period within a day (e.g. often AM-peak, inter-peak, PM-peak only);
- A limited period within a year (e.g. a weekday in a *traffic neutral* month).

Based on supplementary information (e.g. historic information from traffic detectors, or prior knowledge with roads of similar type) it is possible to infer flows for periods outside of those modelled, and produce *Annual Average Daily Total* (AADT) flows for a *Base Year*.

The methodology used to produce *Base Year* flows should be fully documented. It is recognised that the function of such methodologies is to produce best estimates of *flows* throughout the year. The effect of flow variations on speed, and possibly traffic reassignment should also be considered. It may be advisable to check, and if necessary, produce further modelling of certain repeatable conditions (e.g. holiday period traffic, heavily congested network sections) and treat these individually.
If the traffic model available is a few years old, it may be necessary apply a traffic growth factor to the model to produce data for the required Base Year ('the preceding calendar year'). This is also necessary if future noise levels are required for the purpose of action plans. The growth factor ideally should be a local factor for an agglomeration, though a regional/national factor may be suitable for a primary route network. As the growth factor alters demand levels it may be necessary to produce further modelling, to check speeds and possible reassignment. The assumptions used to develop growth factors should be recorded.

### 4.1.9 Final Documentation

Good practice requires that that the above issues are documented and auditable. Traditionally at least two reports have been considered acceptable for a traffic model used to appraise a particular scheme:

- A Model Validation Report (MVR), in which the input data and assumptions used to produce the base model are reported, alongside the validation procedures used. This document forms the basis by which the model is accepted as fit-for-purpose. Additional preliminary documentation on the modelling scope, choice of model and any calibration issues should be included;
- A Model Forecasting Report (MFR), in which considered scenarios and their development are reported, alongside the changes required to the base model, any additional model runs, test results and conclusions.

If an action plan requires the use of a separate model, with substantially different requirements to those of a strategic model, additional reports may be required.
In evaluating the performance of a certain (type of) traffic model, it is important to check how the model performs in the context of noise calculations (see the next section for common traffic modelling problems in this context). This can be done by checking the input and output of the model against available measurements. Also, sensitivity analyses can be useful. In Annex 2, a checklist can be found with which noise and traffic modellers can report the modelling process. The checklist serves to structure the discussion between noise and traffic modellers, and to provide insight into the traffic modelling process – resulting in an (additional) modelling report to be attached to the noise mapping results.

Whilst an acoustician may not necessarily care as to precisely why a particular modelling methodology or software package was selected, what model parameter values were selected, or how a particular validation test was carried out, these details should be recorded in order to ensure future repeatability – so that models from one period of mapping could potentially serve as initial data to the following period.

## 4.2 Common problems in using traffic models for noise calculations

In an ideal situation, traffic models provide exactly the data that are needed by the Harmonoise road noise source model. In theory, this is possible: a traffic model may be built in such a way that it produces values for the desired traffic variables, for the desired roads and desired time periods. In practice, however, there are always certain areas where the traffic model does not perform very well. This is due to the fact that traffic models are usually developed for capacity analyses rather than environmental analyses. In that context, it is not always necessary for the traffic models to produce detailed information on, for instance, vehicle classes and speed distributions. Instead, most traffic models focus on accurate flows and travel times. However, many traffic models are capable of providing the required data and can thus be used in the noise mapping and noise action planning process.

This report contains guidelines that have been developed to deal with data mismatches caused by the different focus (traditionally) of traffic and noise models. The problems generally have to do with:
- vehicle or traffic flow speeds,
- traffic composition (on the road),
- diurnal and long-time patterns of traffic,
- low flow roads,
- intersections, and
- road gradients.

N.B. Other problems in using road and/or traffic data that are not specifically caused by the application of a traffic model can occur. An example is the spatial representation of road segments. There are examples of road networks used in traffic models that show inaccuracies such as “roads going through a building”. In that particular case, there is a simple solution (using ‘shape points’ is possible in most modern traffic models, certainly the commercially available ones). These kinds of problems are treated in WP1 (*Mapping Specifications and GIS*) and WP3 (*Monitoring and Measurement methods*) of the IMAGINE projects and the reader is referred to (forthcoming) deliverables published by those work packages.

Below, the problems specifically having to do with traffic models are explained briefly.

***Speeds***

Modelled speeds do not always meet the accuracy requirements of the END. It is important to obtain accurate vehicle speeds on the busiest roads, because large errors (> 10 km/h) have significant effects (> 1 dB(A)) on calculated noise levels. The uncertainty about modelled speeds is particularly relevant for macroscopic models. Many macroscopic models do not include intersection modelling. The travel times on links include (ideally) delays at intersections, which means that speeds on links leading to or away from an intersection may be underestimated. Another problem is that it is impossible to model congestion accurately with some macroscopic models (especially spill back effects, where a queue extends beyond the adjacent intersection). And macroscopic traffic models do not produce vehicle speed distributions (although dynamic assignment models do produce a distribution of speeds on a link over time - the modelled speeds in each time step). Micro-simulation yields the speed and acceleration of all vehicles in the simulation at any time and thus is much more accurate in that respect. Nevertheless, average

speed and speed distribution depend heavily on parameters of the simulation and on the driver model that is used.
Another problem is that it may be difficult to find vehicle speed data to feed into the traffic model, or to calibrate the model with. Although in many places speed measurements are carried out, these seldom give an accurate picture for all the roads and time periods that are part of a noise map. Most speed measurements are carried out on the busiest roads, and often only for part of the day (usually excluding the evening and night periods). Also, it has to be kept in mind that speeds may vary over a link (which is important for noise calculations) and that measurements only reflect the speeds at the measurement location.

***Traffic composition***
For noise mapping and noise action plans, it is important to discriminate between vehicle types with different noise emissions. In order to produce accurate noise maps, it is desirable to be able to model heavy vehicles and, to a lesser extent, motorised two-wheelers separately. Most traffic models, however, distinguish only one type of traffic: the passenger car, or the passenger car equivalent. For traffic modellers, this is enough to predict travel costs and congestion levels.
The question is whether the model available is based on a single or multi user class demand model and traffic assignment (i.e. all vehicle types are lumped together or there are separate user classes for different vehicle types, e.g. passenger cars, powered two-wheelers, light trucks and heavy trucks). If the demand model and/or the assignment model are single user class based, estimations have to be made for the share of different vehicles types on a link. Single user class models are still common among macroscopic models; microscopic models usually do give the possibility to model several vehicle types. However, in both cases there may be insufficient data on the shares of different vehicle types as found on the road network for accurate estimates.

For motorized two-wheelers, the effect on Lden is not clear. Research into the noise emission of two-wheelers is carried out in WP5 of the IMAGINE project. Their noise contribution is expected to contribute to the $L_{den}$ especially in urban areas (mopeds/scooters), and in the Mediterranean countries (Italy, Spain, Greece). Preliminary results from WP5 show that their overall dB(A) levels are slightly above those for passenger cars, but that their contribution to the lower frequency bands are quite large, especially when accelerating.
Motorized two-wheelers are hardly ever available as a separate user class in traffic model results. The reason for that is that most traffic models are capacity models and motorcycles are not considered to be very important in that respect, because their travel times are hardly influenced by congestion, and their presence on the road (usually) does not influence travel times of other road users. However, if large volumes of two-wheelers are expected and/or their noise emissions are relatively high, it may be necessary to incorporate motorised two-wheelers in traffic models. On the other hand, although annoyance from individual motorcycles and mopeds is often reported, the noise levels in $L_{den}$ are based on yearly averages in which the contribution of individual vehicles is small.

***Diurnal and long-time patterns***
Traffic models very seldom produce flow (or speed) data for representative hours of the day, evening and night. Seasonal variations may be taken into account, but this is not common.
Traffic models usually produce data for either an entire day (weekday or working day), or for the morning or evening peak period (or both). In the IMAGINE WP2.3 report [IMAGINE, 2006b], the importance of incorporating the variation in time (annual, seasonal, weekly, daily) of some selected traffic parameters for $L_{den}$ calculations was investigated in detail. The conclusions were that in general, the importance of temporal resolution decreases when the integration period

increases. When looking e.g. at yearly $L_{den}$ values, the influence of temporal resolution as concerns flow will be limited. On the other hand, variation in speed profiles with time might be more important.

***Low flow roads***
To strictly apply the END, all major roads and all roads in agglomerations have to be mapped. This includes therefore roads on which traffic volumes are (very) low. When traffic models are used to calculate the flows on these roads, three problems occur:

- Networks in traffic models generally leave out low flow or minor roads, since they are not very interesting from a traffic modelling point of view (capacity is not a problem, travel times are not influenced by congestion) and including all of these roads would lead to much longer run times of the models;
- The accuracy of flows calculated by the traffic models is always relatively poor for the lowest scale level roads;
- Measurements of speeds and flows to calibrate the model with are scarce; from a transport planning point of view it is more interesting to measure on busier roads.

The question is: How important is it to obtain accurate traffic estimates for low flow roads? Noise levels on these roads will not be very high. Errors in the traffic estimates will have a smaller effect. Also, the exposure-effect correlation is much less well proven for low exposure.
Exactly how the accuracy requirements for low flow roads translate to traffic flows that can be ignored depends on many factors: the distance from the road to the façades, the driving speed, the fleet composition, traffic dynamics, to name just a few. It therefore seems useful to derive some guidelines for deciding which roads to include in the traffic model.

***Intersections***
The specific dynamics of traffic at intersections can influence local noise emissions. Traffic decelerating and accelerating will cause different noise levels than traffic travelling at a steady speed. Unfortunately, many macroscopic models do not model intersections separately (although they may incorporate the delays experienced on intersections in the travel times and thus speeds). Microscopic models are more suitable to model intersections, but modelling all the intersections in an agglomeration requires a large effort.

***Gradients***
The Harmonoise road noise source model proposes a correction for uphill and downhill driving. This correction is particularly important for trucks. The correction does not consider the fact that trucks will drive slower when going uphill (or that the capacity of the road might decrease). Thus, to find the correct sound power, this speed reduction should be reflected by the traffic model.

# PART II: GUIDELINES FOR THE USE OF TRAFFIC MODELS FOR NOISE MAPPING AND NOISE ACTION PLANNING

# 5 Approaches for traffic modelling for noise maps and action plans

This part of the report provides guidelines for the use of traffic models for noise mapping and noise action planning. Guidelines have been developed for the different purposes considered:

- noise mapping for main roads;
- noise mapping for agglomerations; and
- action planning.

## 5.1 Key for the guidelines

The guidelines have been set up as follows:

***Explanation***

Each guideline starts with an explanation. This explanation goes into why the guideline is needed (problem definition, e.g. accuracy of modelled speeds), and what exactly is the specific problem for which this guideline gives recommendations (e.g. not reliable because of way model works).

***Recommendation***

Subsequently, recommendations are given on how to best apply or how to improve a traffic model for noise mapping or noise action planning. The recommendations are given in text form, but they are also summarised in a table in the form of actions or methods (see Table 2).

**Table 2: Example of the table summarising the guideline for a specific aspect.**

| Guideline for X (e.g. Speeds in static/dynamic macroscopic models | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| | | | |
| | | | |

In this table, an indication of the expected complexity, resulting accuracy and cost of implementing the recommended method is also given. The symbols indicating complexity, accuracy and cost have been kept in line with the symbols used in the Good Practice Guide [WG-AEN, 2006]. Their meaning is given in Table 3 and Table 4 below. Please note that while the symbols and colour coding are similar to those in the Good Practice Guide, there may be differences in interpretation.

**Table 3: Explanation of symbols used to rate methods recommended in a guideline.**

| Colour code to rate method | | | | | |
|---|---|---|---|---|---|
| **complexity** | **colour code** | **accuracy** | **colour code** | **cost** | **colour code** |
| simple | △ | low | △ | inexpensive | △ |
| · | ◇ | · | ◇ | · | ◇ |
| · | ⬠ | · | ⬠ | · | ⬠ |
| sophisticated | ⬡ | high | ⬡ | expensive | ⬡ |

**Table 4: Explanation of symbols used to rate methods recommended in a guideline (accuracy in dB).**

| Colour code to rate Tools | | | | | |
|---|---|---|---|---|---|
| **complexity** | **colour code** | **accuracy** | **colour code** | **cost** | **colour code** |
| simple | △ | low | > 5 dB | inexpensive | △ |
| - | | - | 4 dB | - | |
| - | ◇ | - | 3 dB | - | ◇ |
| - | ⬠ | - | 2 dB | - | ⬠ |
| - | | - | 1 dB | - | |
| sophisticated | ⬡ | high | < 0.5 dB | expensive | ⬡ |

*N.B. The ratings given in the guidelines in this report are based on expert judgment, and, where available, literature on complexity, accuracy and costs. The ratings may therefore not be entirely comparable across guidelines (but should be comparable within guidelines).*

## 5.2 Index to the guidelines

***Noise mapping***

As different traffic model types can be suitable for noise mapping (for main roads and for agglomerations), guidelines are given for two groups of models (hereafter referred to as ‘model types’), see Table 5:

- static/dynamic macroscopic models; and
- micro-simulation (& continuum models).

The aspects discussed in the guidelines for noise mapping are the ‘common problems’ (described in paragraph 4.2):

- speed;
- acceleration;
- traffic composition;
- diurnal and long-time pattern;
- low flow roads;

- intersections; and
- gradients.

For some of these aspects, the guidelines may differ per model type. For other aspects, the approach will be the same or very similar. The structure of the guidelines is such that all aspects have been given their own subparagraph (though that paragraph may simply redirect the reader to an earlier paragraph containing the applicable guideline).

***Noise action planning***

For noise action planning, the guidelines have been divided into a general guideline on noise action planning and four guidelines pertaining to different effects that might be expected of measures to reduce road noise (see Table 6):

- effects on the link level: only (very) local effects are expected from the measure;
- effects on the network level: the measure may lead to rerouting of traffic;
- effects on departure time choice: the measure may result in a different distribution of traffic over the day (diurnal pattern); and
- effects on destination/mode choice: the measure may result in a shift in destinations traveled to or modes of transport used (demand effects).

**Table 5: Overview of noise mapping guidelines and the paragraph in which to find them.**

| Purpose | Para-graph | Model type | Aspects discussed | Sub-paragraph |
|---|---|---|---|---|
| Noise mapping for main roads | 6.1 | Static/dynamic macroscopic models | Speed | 6.1.1 |
| | | | Acceleration | 6.1.2 |
| | | | Traffic composition | 6.1.3 |
| | | | Diurnal and long-time pattern | 6.1.4 |
| | | | Low flow roads | 6.1.5 |
| | | | Intersections | 6.1.6 |
| | | | Gradient | 6.1.7 |
| | 6.2 | Micro-simulation | Speed | 6.2.1 |
| | | | Acceleration | 6.2.2 |
| | | | Traffic composition | 6.2.3 |
| | | | Diurnal and long-time pattern | 6.2.4 |
| | | | Low flow roads | 6.2.5 |
| | | | Intersections | 6.2.6 |
| | | | Gradient | 6.2.7 |
| Noise mapping for agglomerations | 7.1 | Static/dynamic macroscopic models | Speed | 7.1.1 |
| | | | Acceleration | 7.1.2 |
| | | | Traffic composition | 7.1.3 |
| | | | Diurnal and long-time pattern | 7.1.4 |
| | | | Low flow roads | 7.1.5 |
| | | | Intersections | 7.1.6 |

| | | | | |
|---|---|---|---|---|
| | | | Gradient | 7.1.7 |
| | 7.2 | Micro-simulation | Speed | 7.2.1 |
| | | | Acceleration | 7.2.2 |
| | | | Traffic composition | 7.2.3 |
| | | | Diurnal and long-time pattern | 7.2.4 |
| | | | Low flow roads | 7.2.5 |
| | | | Intersections | 7.2.6 |
| | | | Gradient | 7.2.7 |

**Table 6: Overview of noise action planning guidelines and the paragraph in which to find them.**

| Subject | Paragraph |
|---|---|
| General guideline | 7.1 |
| Effect on link level | 7.2 |
| Effect on network level | 7.3 |
| Effect on departure time choice | 7.4 |
| Effect on destination/mode choice | 7.5 |

# 6 Guidelines for the use of traffic models for noise mapping for main roads

## 6.1 Noise mapping for main roads using static/dynamic macroscopic models

### 6.1.1 Speed

***Explanation***

For noise modelling, accuracy of speeds is more important than accuracy of traffic flows (note that an error of 10km/h in mean speed can lead to a difference of 1dB). When using speeds as produced by traffic models, it has to be kept in mind that traffic models were not designed specifically to produce accurate speeds. Instead, the focus is on reliable travel times and vehicle flows. This means that the reliability of modelled speeds should be checked. For instance, speeds may be underestimated when travel times are used to calculate average speeds. In models that do not include intersection modelling, the delays experienced at an intersection have to be incorporated into the time spent on a link (leading to or from an intersection). In some cases, traffic modellers use the travel time on road segments to calibrate the vehicle flows on the network. In that case, the resulting speeds may not be realistic.

***Recommendation***

The modelled speeds should be validated. Ideally, this is an in-depth validation incorporating the speed evolutions in the neighbourhood of intersections. Also, speed measures along a road segment can be taken into account (e.g. speed humps).
A less extensive validation of the speeds resulting from the model can be done by checking the modelled speeds against measured speeds.
For both types of validation mentioned it is necessary to recalibrate when the results are not accurate enough. Although it is not very common in the traffic modelling world, it is possible to calibrate the speeds, using flows as the parameter to be adjusted. As speeds are considered more important than flows, this can be a good option.
A last option is to neglect modelled speeds and use speed limits when modelling noise levels. This can be a good approximation for situations with low vehicle flows (e.g. low flow roads, night period). On busier roads, the level of accuracy is not guaranteed, as speeds derived from speed limits are generally higher than the modelled speeds there.

| **Guideline for traffic speed in static/dynamic macroscopic models (main roads)** | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Use speeds derived from speed limits instead of modelled speeds | △ | △ | △ |
| Improve modelled speeds by additional validation | ◇ | ◇ | ◇ |
| In-depth validation of modelled speeds incorporating the modelling of intersections | ⬠ | ⬠ | ⬠ |

### 6.1.2 Acceleration

***Explanation***

At mid-link locations, links below capacity may be regarded as having almost constant speed. At link entries and exits, mean speeds fluctuate as vehicles accelerate and decelerate. The rate of acceleration or deceleration affects noise generation. Macroscopic models do not tend to explicitly use acceleration rates – rather they use more abstract demand/capacity concepts to estimate queue length and delays at junctions.

Vehicles may be subject to low (i.e. $<0.8 m/s^2$) acceleration rates at mid-link locations during congested conditions.

***Recommendation***

For strategic noise mapping using macroscopic models it is suggested that acceleration/ deceleration rates ***will not be explicitly included in modelling***. Instead, appropriate intersection emission corrections should be used (see 6.1.6) – assuming the type of intersection (signalised, priority, roundabout) is known. The GPG [WG-AEN, 2006] also provides rough estimates of the size of acceleration and deceleration zones (tool 6.1).

If detailed analysis is required of the acceleration/deceleration and queuing zones around a junction is required then it is suggested that:

1. Microsimulation of the intersection(s) is considered, or;
2. A macroscopic model capable of estimating queue lengths and vehicle delays at junctions is used (e.g. TRIPS, SATURN, CONTRAM) to provide data for intersection corrections, as per 6.1.6, or;
3. A separate macroscopic intersection modelling application (e.g. TRANSYT) is used to obtain queue lengths, then step 2 is followed.
4. The size of the acceleration/deceleration zones are estimated from an appropriate trajectory profile or by assuming constant acceleration/deceleration rate, or;
5. The guidance of the GPG is followed.

For accurate modelling all of the above may require onsite data collection. Further discussion of the issue may be found in the IMAGINE WP2.4 report [IMAGINE, 2006a] in section 4.

| **Guideline for acceleration in macroscopic models (main roads)** | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy[1]** | **Cost** |
| Do not include – treat speeds as constant | △ | △ | △ |
| Calculate accel/decel zone sizes as per GPG, then use 6.1.6 | △ | ◇ | △ |
| Calculate accel/decel zone sizes using assumed acceleration profiles, calculate queuing zone size from separate modelling application, or provided tools in macroscopic package. | ◇ | ◇ | ◇ |
| Use microsimulation model for intersections | ⬠ | ⬠ | ⬠ |

[1] Effects will be localised to within an approximate 300m radius of major intersections, For most urban roads effects will be very local – i.e. within a 100m radius of the junction)

### 6.1.3 Traffic composition

***Explanation***

For a good noise prediction, it is necessary to quantify different vehicle types in traffic model results: passenger cars, medium and heavy trucks and motorised two-wheelers. Not all static and dynamic traffic models provide multi vehicle class information. And even if they do (the so-called multi user class models: MUC), the traffic data that is used to build the model can be insufficient.

***Recommendation***

If it is possible, use a multi user class assignment model. This is only possible if a demand model with these user classes is available, and distinguishes vehicle categories as needed for noise modelling. Then the assignment can be carried out using a MUC-origin-destination matrix containing trips from the demand model. The result of the MUC-assignment procedure consists of loads per link per vehicle type (user class). Check whether the quality of base data for the MUC-model is sufficient. See for further details on measuring data for different vehicle classes the IMAGINE WP2.4 report [IMAGINE, 2006a].
If it is not possible to use a MUC-model, see the GPG [WG-AEN, 2006] and section 3.2 of the IMAGINE WP2.3 report [IMAGINE, 2006b] for further information on possible strategies.

| Guideline for traffic composition in static/dynamic macroscopic models (main roads) | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| No multi user class assignment – use single user class assignment provided by model | ⬠ | △ | △ |
| Use multi user class static assignment (see section 3.2 of the IMAGINE WP2.3 report for MUC-assignment, and the IMAGINE WP2.4 report for advice on data collection) | ⬠ | ◇ | ◇ |
| Use multi user class dynamic assignment (see section 3.2 of the IMAGINE WP2.3 report for MUC-assignment, and the IMAGINE WP2.4 report for advice on data collection) | ⬡ | ⬠ | ⬠ |

### 6.1.4 Diurnal and long-time patterns

***Explanation***

The END imposes the use of yearly averaged $L_{den}$ as an indicator. Macroscopic traffic models often produce instantaneous flow and vehicle speed over a full year. The problem can be split into several partial problems: a) the traffic model does not include diurnal pattern, only peak hour or representative hour for the day and the night are available; b) the traffic model only considers a typical (week)day, no weekend data; c) the traffic model only produces data for busy days, traffic flow and speed are not available for holiday periods, special winter conditions.
For main roads and at larger distances the diurnal and seasonal detail of the available source data couples to the detail taken into account in the propagation model because of changing meteorological conditions. E.g. morning rush hour may coincide with temperature inversion.

***Recommendation***

The recommendations depend on the detail of the propagation modelling. The choice of detail in the propagation modelling is part of WP1. Two cases are considered:

a) low influence of meteorological conditions, thus propagation under average meteo is sufficient;
b) strong influence of meteorological conditions, thus propagation and source power needs to be coupled on a (sub) hourly basis.

For case a) the accuracy of the sound power level produced on a road segment is the relevant parameter.

| Guideline for diurnal / weekly patterns, low meteorological influence, in static/dynamic macroscopic models (main roads) | | | |
|---|---|---|---|
| **Situation** | **Complexity** | **Accuracy [1]** | **Cost** |
| Traffic model produces hourly traffic data for full week | | | |
| Traffic model produces hourly traffic data for one representative day of the working week and one representative day of the weekend: assume same for all working / weekend days | | < 0.5 dB | |
| Traffic model produces hourly traffic data for one representative day of the working week: assume same for all days [2] | | < 0.5 dB | |
| Traffic model produces working day traffic data as representative value for day and representative value for night [2]<br>a) use measurements at representative point to refine<br>b) attribute 75% to day, 25% to night | | < 0.5 dB<br>1 dB | |
| Traffic model produces working day traffic data as representative value for day [2]<br>a) use measurements at representative point to refine<br>b) attribute 70% to day, 20% to evening and 10% to night | | < 0.5 dB<br>2 dB | |

[1] 95% confidence interval assuming normal distribution over all cases occurring, assuming negligible error if hourly data are available.

[2] exclude areas near strong weekend-traffic attractors.

The effect of neglecting annual fluctuations depends very strongly on local situations. In general the error introduced will be much smaller than 0.5 dB, but for specific places season-dependent traffic may be important and has to be studied in detail.

For case b) the influence of insufficient temporal detail on the calculated noise emission depends on the weather conditions and thus the season that occur and the distance / amount of screening.

| Guideline for diurnal / weekly patterns, strong meteorological influence, in static/dynamic macroscopic models (main roads) | | | |
|---|---|---|---|
| **Situation** | **Complexity** | **Accuracy** | **Cost** |
| Traffic model produces hourly traffic data for each day of a representative (meteo) period. | | | |
| Traffic model produces daily total traffic flow for each day of a representative (meteo) period: attribute 70% to day, 20% to evening and 10% to night | | 1 dB | |
| Traffic model produces data for one day | | | |

Attention must be paid to combined effects of diurnal traffic fluctuations and speed for roads near congestion. Accuracy estimates in the guidelines above may become up to 2dB or worse.

### 6.1.5 Low flow roads

By definition, low flow roads are outside of modelling requirements for main roads.

### 6.1.6 Intersections

***Explanation***

The detailed traffic flow near intersections is rather complex. Vehicles slow down when approaching the intersection. There may be a multiple start-stop period. Finally traffic accelerates when leaving the intersection. Traffic intensity on all arms, percentage of heavy vehicles, turning rate, number of lanes, allowed speed and priority rules influence this dynamic behaviour. Macroscopic traffic models do not attempt to model this detailed behaviour. At most an additional delay (or reduced average speed) is included in the model.
The methodology for including the effect of intersections depends on the spatial resolution required for the noise map. The required spatial resolution is a subject in WP1 of the IMAGINE project.

***Recommendation***

If the required spatial resolution is low, the presence of the intersection can be ignored, at the expense of some (usually small) error in the section of the road closest to the intersection. If the required spatial resolution is high, it may be desirable to derive the speed and acceleration profiles near intersections, and apply these in the road noise source model.

| Guideline for intersections, in static/dynamic macroscopic models (main roads) | | | |
|---|---|---|---|
| **Situation** | **Complexity** | **Accuracy** | **Cost** |
| Required spatial resolution >500m; intersection ignored | | < 0.5 dB | |
| Required spatial resolution >300m; intersection ignored | | 1 dB | |
| Required spatial resolution <300m; apply local speed and acceleration profiles when available [1] | | | |

[1] WP5 of the IMAGINE project (road noise sources) intends to provide default speed and acceleration profiles intersections (forthcoming). Also, in the report on WP2.3 [IMAGINE, 2006b] a case study can be found into speeds and accelerations and resulting noise levels at different intersections, based on micro-simulation. In this case study it was found that corrections to the sound power of 10m road segments typically are at most of the order of 1 to 2 dB(A). N.B. This estimate is based on an analysis of a limited number of intersection configurations (see the IMAGINE WP2.3 report), but it is likely that it can be applied in other situations as well.

### 6.1.7 Gradients

***Explanation***

The road noise source model has a correction factor for gradients. However, gradients may also affect traffic flows, resulting in e.g. lower speeds (and lower capacity), especially when there is a considerable amount of heavy vehicles and no separate lane for them. This effect is not taken into account by the noise model, so it can be desirable to be able to model that kind of effects in the traffic model used, if it is expected that gradients play an important role.

***Recommendation***
First, check whether gradients are taken into account in the traffic model. If this is not the case and it is expected that gradients play an important role, there are several options to incorporate the effect of gradients. Traffic model experts can adapt the characteristics of the links in the road network with significant gradients. Preferably, this is done for different vehicle types (e.g. passenger cars, heavy vehicles) separately. Characteristics that can be changed are, for example, the maximum speed reached and/or the speed-flow curve, and capacity. Information on relationships between speeds and gradients (and length of the slope and share of heavy vehicles) can be found in publications like the „Handbuch für die Bemessung von Straßenverkehrsanlagen" [FGSV, 2001] and chapter 23 of the Highway Capacity Manual [TRB, 2000]. It may be necessary to divide long links in several shorter links, to better adapt the characteristics of the links to the traffic situation found on the road.

| **Guideline for gradients in static/dynamic macroscopic models (main roads)** | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Check whether traffic model takes gradients into account | | n.a. | |
| Adapt characteristics of links with gradients, e.g. maximum speed / speed-flow curve, capacity, for all vehicles. If possible, separately for heavy vehicles. Divide links into several links if needed | | | |
| Adapt characteristics of links with gradients, e.g. maximum speed / speed-flow curve, capacity, for different vehicle categories separately. Divide links into several links if needed | | | |

## 6.2 Noise mapping for main roads using micro-simulation

### 6.2.1 Speed

For noise modelling, accuracy of speeds is more important than accuracy of traffic flows. When using speeds as produced by traffic models, it has to be kept in mind that traffic models were not designed specifically to produce accurate speeds. Instead, the focus is on reliable travel times and vehicle flows. This means that the reliability of modelled speeds is not guaranteed. Another potential problem is the loss of information if averaged speeds are used instead of individual vehicle speeds.

***Recommendation***
With micro-simulation, in theory, two approaches are possible:

1. aggregate vehicle speeds in the traffic model;
2. aggregate vehicle speeds in the noise model (this is the more common approach).

In the first case, the vehicle speeds are aggregated to a mean speed and speed distribution on a road section, which are fed into the noise model. In the second case, the individual vehicle speeds are directly fed into the noise model in which subsequently the noise levels are aggregated.

In either case, it is advisable to validate the modelled speeds with speed measurements.

| Guideline for traffic speed in micro-simulation models (main roads) | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Use mean speeds from model (if possible, add information about speed distribution) | △ | △ | △ |
| Idem, with additional validation | ◇ | ◇ | ◇ |
| Use individual vehicle speeds from model and calculate noise level directly. | ⬠ | ◇ | ⬠ |
| Idem, with additional validation. | ⬡ | ⬠ | ⬡ |

### 6.2.2 Acceleration

***Explanation***

As explained in section 6.1.2 acceleration/deceleration rates near intersections will affect source noise generation. Micro-simulation models use a variety of defined acceleration/deceleration rates in their operation; to control vehicle kinematic behaviour during general car-following and to control behaviour on approach to and on departure from intersections.

***Recommendation***

The acceleration values required depend on the modelling package used. Most require maximum rates, whilst some require 'normal' or 'comfortable' values. Seeking advice from the application vendor on appropriate rates is recommended.
Note that the actual acceleration rates produced by micro-simulation models will depend on other model parameters such as vehicle spacing coefficients, driver and brake reaction times, gap acceptance times, turning (e.g. side- friction) parameters, simulation time step (update rate) etc. Such parameters may have more effect on overall model calibration/validation, and output acceleration, than maximum acceleration rates.

It is suggested that, in the absence of more specific data, for the first three HARMONOISE vehicle categories the following limit values could be used:

- Cars (category 1): Maximum acceleration +3.0m/s$^2$, Maximum deceleration -4.0 m/s$^2$
- Light vehicles (category 2): Maximum acceleration +1.5m/s$^2$, Maximum deceleration -3.0m/s$^2$
- Heavy vehicles (category 3): Maximum acceleration +1.0m/s$^2$, Maximum deceleration -3.0m/s$^2$
- Powered two-wheelers (category 4): Maximum acceleration +5.0m/s$^2$, Maximum deceleration -5.0m/s$^2$

There is insufficient data to confidently assess the fifth HARMONOISE categories (other heavy vehicles).

| Guideline for traffic acceleration in micro-simulation models (main roads) | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Use default limit acceleration rates (see above) for individual vehicle categories | △ | ◇ | △ |
| Use model/vendor specified rates for individual vehicle categories | △ | ◇ | △ |
| Use rates calibrated and validated from on street measurements | ◇ | ⬠ | ◇ |
| Use rates calibrated and validated from controlled vehicle measurements | ⬡ | ⬠ | ⬡ |

### 6.2.3 Traffic composition

***Explanation***

For a good noise prediction, it is necessary to quantify different vehicle types in traffic model results: passenger cars, medium and heavy trucks and motorised two-wheelers. Traffic simulation models are virtually always capable to do this, because they model each vehicle individually. However, the demand data for this model type is often poorly estimated, which can lead to incorrect prediction of traffic loads and speeds. As a result, calibration and validation of simulation models is often a problem.

***Recommendation***

If the measured traffic data available is of insufficient quality, it is recommended to try to do automatic measurements which take vehicle length into account, as described in section 4.4.2 of the IMAGINE WP2.4 report.
If the equipment to do automatic measurements is available, the data can be relatively easily obtained. If this equipment is not available, the choice has to be made to either measure by hand, or to invest in this type of equipment.

| Guideline for traffic composition in micro-simulation models (main roads) | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Obtain data for validation of traffic composition when measurement equipment (capable of distinguishing different vehicle types) is available | ◇ | n.a. | ◇ |
| Obtain data for validation of traffic composition when measurement equipment (capable of distinguishing different vehicle types) is not available | ◇ | n.a. | ⬡ |
| Calibrate traffic composition | ⬠ | n.a. | ◇ |

### 6.2.4 Diurnal and long-time patterns

***Explanation***

In addition to the need for obtaining traffic demand descriptions for periods of one or several days, micro-simulations typically will require long simulation times. The cost for calculating diurnal and long-time patterns is therefore greater.

***Recommendation***

Recommendations and guidelines given in 6.1.4 can be applied.

### 6.2.5 Low flow roads

By definition, low flow roads are outside of modelling requirements for main roads.

### 6.2.6 Intersections

***Explanation***

Micro-simulation models include a detailed description of the complex traffic flow near and on intersections, and can provide speed and acceleration profiles.

***Recommendation***

There is little advantage in averaging traffic parameters over a section of road near an intersection, so it is proposed to calculate noise emission by all vehicles modelled and to average sound power over road segments.

| Guideline for intersections in micro-simulation models (main roads) | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Calculating noise for individual vehicles based on traffic model, taking into account speed and acceleration. | ◇ | ⬠ | △ |

### 6.2.7 Gradients

***Explanation***

The road noise source model has a correction factor for gradients. However, gradients may also affect traffic flows, resulting in e.g. lower speeds (and lower capacity), especially when there is a considerable amount of heavy vehicles and no separate lane for them. This effect is not taken into account by the noise model, so it can be desirable to be able to model that kind of effects in the traffic model used, if it is expected that gradients play an important role.

***Recommendation***

Check whether gradients are taken into account in the traffic model. Many micro-simulation models have a parameter for gradients (which may distinguish between vehicle types). This parameter can be used to influence the speed and acceleration of vehicles, and may be changed to reflect local circumstances.
Information on relationships between speeds and gradients (and length of the slope and share of heavy vehicles) can be found in publications like the „Handbuch für die Bemessung von Straßenverkehrsanlagen“ [FGSV, 2001] and chapter 23 of the Highway Capacity Manual [TRB, 2000]. It may be necessary to divide long links in several shorter links, to better adapt the characteristics of the links to the traffic situation found on the road.

| Guideline for gradients in micro-simulation models (main roads) | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Check whether traffic model takes gradients into account | △ | n.a. | △ |
| Adapt gradient parameter(s) if necessary | △ | ⬠ | △ |

# 7 Guidelines for the use of traffic models for noise mapping for agglomerations

## 7.1 Noise mapping for agglomerations using static/dynamic macroscopic models

### 7.1.1 Speed

As section 6.1.1.

### 7.1.2 Acceleration

As section 6.1.2.

### 7.1.3 Traffic composition

As section 6.1.3.

### 7.1.4 Diurnal and long-time patterns

***Explanation***

The END imposes the use of yearly averaged $L_{den}$ as an indicator. Macroscopic traffic models often produce instantaneous intensity and vehicle speed over a full year. The problem can be split into several partial problems: a) the traffic model does not include diurnal pattern, only peak hour or representative hour for the day and the night are available; b) the traffic model only considers a typical (week)day, no weekend data; c) the traffic model only produces data for busy days, traffic flow and speed are not available for holiday periods, special winter conditions.

***Recommendation***

The accuracy of the sound power level produced on a road segment is the relevant parameter.

| Guideline for diurnal / weekly patterns in static/dynamic macroscopic models (agglomerations) | | | |
|---|---|---|---|
| **Situation** | **Complexity** | **Accuracy** | **Cost** |
| Traffic model produces hourly traffic data for full week | ◇ | ⬡ | ⬠ |
| Traffic model produces hourly traffic data for one representative day of the working week and one representative day of the weekend: assume same for all working / weekend days | ◇ | ⬠ | ⬠ |
| Traffic model produces hourly traffic data for one representative day of the working week: assume same for all days [1] | ◇ | ⬠ | ◇ |
| Traffic model produces working day traffic data as representative value for day and representative value for night [1]<br>a) use measurements at representative point to refine<br>b) attribute 75% to day, 25% to night | ⬠<br>△ | ⬠<br>◇ | ⬠<br>△ |
| Traffic model produces working day traffic data as representative value for day [1]<br>a) use measurements at representative point to refine<br>b) attribute 70% to day, 20% to evening and 10% to night | ⬠<br>△ | ⬠<br>△ | ⬠<br>△ |

[1] exclude areas near strong weekend-traffic attractors.

### 7.1.5 Low flow roads

***Explanation***

For low flow roads, the relative magnitude of errors and uncertainties in flow volumes may result in relatively large overall errors and uncertainties in sound levels. Many people live close to low flow roads in agglomerations – so errors in noise exposure statistics may be significant.

Given that low flow roads will generally operate with speeds under 50km/h, if traffic streams are relatively freely flowing, then it is more important to ascertain relatively accurate flow volumes and establish the presence of heavier vehicle categories or motorcycles.

It is noted that many suburban areas have appreciable flows of medium-heavy vehicles (i.e. buses) during the daytime period. Presence of schools in suburban areas may add to particularly high car and bus demand on adjacent links during certain periods of the day.

Possible solutions to this issue include:

1. Primary bus routes may be identified from timetable information and direct observations of service frequency made.
2. Public transport information may be coded into the model as a separate user class, based on timetable/service information from operators.
3. No attempt is made to model the issue.

Additional localised problems may arise when excessive heavy vehicle traffic is present within a particular area, due to specific commercial activities or due to quirks of the road network. It is suggested that liaison between modellers, local authorities, fleet operators and the general public would assist in the identification of such problems, and case-by-case corrections made to maps, prior to general publication if necessary.

***Recommendation***

It is unlikely that flow, speed or composition information will be available from a static/dynamic models for low flow roads. However, a number of creative solutions to the above problems are suggested, but may add considerable time, cost and complexity in developing macroscopic models. These solutions require direct measurement of traffic parameters, access to urban planning or census information, or most likely both.

What little traffic information for low flow roads that is available within existing macroscopic models may represent aggregate data over a number of routes. In order to ensure the correct assignment of vehicles within the model, it would be necessary to:

- Code new zones and links within the model (and possibly break existing links into smaller sections and resize existing zones to allow the correct assignment of vehicles to the network);
- Measure, or calculate by some means, demand levels for the network at the proper resolution for the new zones;

Alternately, a simpler method of calculating required parameters, or deriving them from observed values, outside of the macroscopic model could be applied. Results from this method could then be combined with results for main roads from the macroscopic model to give an overall picture for the agglomeration.

For further information see the WP2.3 report [IMAGINE, 2006b], section 3.4 and the WP2.4 report [IMAGINE, 2006a], section 2.1.2.

| **Guideline for traffic composition in static/dynamic macroscopic models (agglomerations)** | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Take direct measurements of flow, speed and composition on roads. Use these values directly. | | | |
| Take direct measurements of flow, speed an composition on a representative sample of roads. Scale data for use with other roads by appropriate metrics. | | | |
| Resize model zones. Add additional links. Calibrate new model against representative measurements (as above). | | | |
| Generate flow volumes based on assumed trip generation rates (e.g. trips per household), scaled by appropriate metrics. | | | |
| Assume traffic parameters based on road type – (e.g. See WG-AEN GPG [WG-AEN, 2006], Toolkit 2, Tool 2.5 and Toolkit 4, Tool 4.5). | | | |

[1] Direct measurements should ideally be split into the correct day, evening and night periods, else assumptions must be made regarding diurnal profiles.

[2] Appropriate metrics for scaling may include: road lengths, housing density, population/population density, household statistics etc.

[3] This assumes that adequate trip rate data is available from other sources – else extensive additional survey work would be required.

### 7.1.6 Intersections

***Explanation***

The detailed traffic flow near intersections is rather complex. Vehicles slow down when approaching the intersection. There may be a multiple start-stop period. Finally traffic accelerates when leaving the intersection. Traffic intensity on all arms, percentage of heavy vehicles, turning rate, number of lanes, allowed speed and priority rules influence this dynamic behaviour. Macroscopic traffic models do not attempt to model this detailed behaviour. At most an additional delay (or reduced average speed) is included in the model. However, when doing noise calculations for agglomerations, it can be desirable to use very accurate traffic data for intersections.
The methodology for including the effect of intersections depends on the spatial resolution required for the noise map. The required spatial resolution is a subject in WP1 of the IMAGINE project.

***Recommendation***

Apply local speed and acceleration profiles near intersections if accurate results are required.

| Guideline for intersections in static/dynamic macroscopic models (agglomerations) | | | |
|---|---|---|---|
| **Situation** | **Complexity** | **Accuracy** | **Cost** |
| Ignore intersections | △ | ◇ | △ |
| Apply local speed and acceleration profiles when available [1] | ⬠ | ⬠ | ◇ |

[1] WP5 of the IMAGINE project (road noise sources) intends to provide default speed and acceleration profiles intersections (forthcoming). Also, in the report on WP2.3 [IMAGINE, 2006b] a case study can be found into speeds and accelerations and resulting noise levels at different intersections, based on micro-simulation. In this case study it was found that corrections to the sound power of 10m road segments typically are at most of the order of 1 to 2 dB(A). N.B. This estimate is based on an analysis of a limited number of intersection configurations (see the IMAGINE WP2.3 report), but it is likely that it can be applied in other situations as well.

### 7.1.7 Gradients

***Explanation***

The road noise source model has a correction factor for gradients. However, gradients may also affect traffic flows, resulting in e.g. lower speeds and lower capacity, especially when there is a considerable amount of heavy vehicles and no separate lane for them. This effect is not taken into account by the noise model, so it can be desirable to be able to model that kind of effects in the traffic model used, if it is expected that gradients play an important role.

***Recommendation***

First, check whether gradients are taken into account in the traffic model. If this is not the case and it is expected that gradients play an important role, there are several options to incorporate the effect of gradients. Traffic model experts can adapt the characteristics of the links in the road network with significant gradients. Speeds near intersections may also be affected (e.g. because of vehicles accelerating at a slower rate). Preferably, the changes are implemented for different vehicle types (e.g. passenger cars, heavy vehicles) separately. Characteristics that can be changed are, for example, the maximum speed reached and/or the speed-flow curve, and capacity. Information on relationships between speeds and gradients (and length of the slope and share of heavy vehicles) can be found in publications like the „Handbuch für die Bemessung von

Straßenverkehrsanlagen" [FGSV, 2001] and chapter 23 of the Highway Capacity Manual [TRB, 2000]. It may be necessary to divide long links in several shorter links, to better adapt the characteristics of the links to the traffic situation found on the road.

| **Guideline for gradients in static/dynamic macroscopic models (agglomerations)** | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Check whether traffic model takes gradients into account | △ | n.a. | △ |
| Adapt characteristics of links with gradients, e.g. maximum speed / speed-flow curve, capacity, for all vehicles. If possible, separately for heavy vehicles. Divide links into several links if needed | ⬠ | ◇ | ◇ |
| Adapt characteristics of links with gradients, e.g. maximum speed / speed-flow curve, capacity, for different vehicle categories separately. Divide links into several links if needed | ⬡ | ⬠ | ⬠ |
| Adapt speed and/or acceleration near intersections (when the gradient influences the speed/acceleration at the intersection) | ⬠ | ⬠ | ◇ |

## 7.2 Noise mapping for agglomerations using micro-simulation

### 7.2.1 Speed

As section 6.2.1.

### 7.2.2 Acceleration

As section 6.2.2.

### 7.2.3 Traffic composition

As section 6.2.3.

### 7.2.4 Diurnal and long-time patterns

As section 6.2.4.

### 7.2.5 Low flow roads

***Explanation***

For low flow roads, the relative magnitude of errors and uncertainties in flow volumes may result in relatively large overall errors and uncertainties in sound levels. Many people live close to low flow roads in agglomerations – so errors in noise exposure statistics may be significant.

***Recommendation***

It may not be practical or desirable to model low flow roads using micro-simulation models for strategic noise mapping. It is suggested that other solutions are sought – see paragraph 7.1.5, the WP2.3 report [IMAGINE, 2006b], section 3.4 and WP2.4 report [IMAGINE, 2006a], section 2.1.2.

If a micro-simulation mode is to be used, similar problems as mentioned in paragraph 7.1.5 regarding the use of macroscopic models would need to be overcome – specifically:

- The need for a highly detailed representation of the road network, with residential links broken down into short link sections;
- The need to obtain or generated demand data at the appropriate resolution for the network.

However, for action planning micro-simulation models may be ideal for modelling the effect of localised problems such as bus operations, local heavy vehicle operations, traffic calming measures etc., if adequate supporting information can be obtained.

### 7.2.6 Intersections

As section 6.2.6.

### 7.2.7 Gradients

***Explanation***

The road noise source model has a correction factor for gradients. However, gradients may also affect traffic flows, resulting in e.g. lower speeds and lower capacity, especially when there is a considerable amount of heavy vehicles and no separate lane for them. This effect is not taken into account by the noise model, so it can be desirable to be able to model that kind of effects in the traffic model used, if it is expected that gradients play an important role.

***Recommendation***

Check whether gradients are taken into account in the traffic model. Many micro-simulation models have a parameter for gradients (which may distinguish between vehicle types). This parameter can be used to influence the speed and acceleration of vehicles, and may be changed to reflect local circumstances.
Information on relationships between speeds and gradients (and length of the slope and share of heavy vehicles) can be found in publications like the „Handbuch für die Bemessung von Straßenverkehrsanlagen“ [FGSV, 2001] and chapter 23 of the Highway Capacity Manual [TRB, 2000]. It may be necessary to divide long links in several shorter links, to better adapt the characteristics of the links to the traffic situation found on the road.

| **Guideline for gradients in micro-simulation models (agglomerations)** | | | |
|---|---|---|---|
| **Method** | **Complexity** | **Accuracy** | **Cost** |
| Check whether traffic model takes gradients into account | △ | n.a. | △ |
| Adapt gradient parameter(s) if necessary | △ | ⬠ | △ |

# 8 Guidelines for the use of traffic models for noise action planning

When action plans have to be made, traffic models may again be used to provide road traffic data for the noise model. The suitability of models depends, in this case, on the expected effect of measures proposed to reduce noise levels. The WP2.3 report *Development of strategies for the use of traffic models for noise mapping and action planning* [IMAGINE, 2006b] gave some considerations for modelling four types of measures, namely reduction of traffic intensity, changing fleet composition, reducing traffic speed and making traffic less dynamic. In this chapter, more general considerations regarding the suitability of models for measures with specific expected effects are given.

## 8.1 General guideline

***Explanation***
Determining the effects of measures to reduce noise by changing traffic patterns can be very complex. Apart from the direct effects, there are usually side-effects that can be substantial. A clear example of this is closing a certain street to heavy vehicles. The effects for this street are clear, but where do the heavy vehicles go that used to pass through the street? Will they cause noise problems elsewhere? It is therefore important to consider the expected effects of measures and to take these expected effects into account when determining which traffic model should be used.

***Recommendation***
Define the measure and list the expected effects. Questions to ask are:
- On what level are effects expected:
  - on the link level only;
  - on the network level.
- Are effects expected such as:
  - changes in departure time;
  - changes in destination and mode choice.

Measures nearly always have effects in more than one of the above listed categories. Effects on the network level, such as traffic choosing another route through the network (rerouting), are probably the most common, so in most cases a traffic model should be chosen that can deal with route choice. See the paragraphs 8.2-8.5 for further guidance on how to deal with expected effects on the link level and network level, and on departure times and destination and mode choice.

It is also important to check how difficult it is to implement a measure in a given traffic model. Not every parameter of a traffic model will be defined as expected from the name of it, for reasons having to do with calibration (to account for variables not included separately in the model), and thus unexpected effects may occur when these parameters are changed. An example of such a parameter is the link speed (an input to the traffic model), which is probably not the maximum allowed speed. So when a speed limit is reduced, it might be complicated to figure out the desired change in link speed. In such cases, it is important to discuss the objective of the measure with the traffic modelling expert.

## 8.2 Effect on link level

***Explanation***
Examples of measures that probably only have an effect on a specific (set of) links are 30 km zones, changes in geometry (e.g. chicanes) and speed humps on non-main roads. Basically, this concerns measures that will change the driving pattern of vehicles only very locally, and that will not change the route choice of vehicles (for instance because the measure is implemented on streets with destinations that cannot be reached via other routes).
When measures such as speed humps are implemented on main streets, rerouting of traffic may occur if there is an alternative route. In that case, the measure should be implemented in a traffic model capable of dealing with route choice.

***Recommendation***
Micro-simulation models are the most suitable to model measures with a very local effect (a continuum model is also suitable). In these models, it is relatively easy to implement such measures and to evaluate the changes in driving behaviour.

## 8.3 Effect on network level

***Explanation***
Network effects, due to rerouting of traffic, can be expected from all measures influencing travel times on a specific link/route significantly (for which alternative routes are available). Examples of such measures are closing streets to all motorised traffic or to specific vehicle categories such as heavy vehicles, a new ring road, changing traffic lights settings (e.g. green waves, or ramp metering), parking guidance systems, reducing the speed limit, installing traffic lights, speed humps etc..

***Recommendation***
Check whether the available traffic model can deal with route choice. In most cases, this will mean that static or dynamic macroscopic models are the most suitable. For small networks micro-simulation may also be suitable, but not all micro-simulation models have a good route choice function.

## 8.4 Effect on departure time choice

***Explanation***
Examples of measures influencing departure times are pricing measures (e.g. peak hour / congestion charges), and bans on (certain types of) vehicles at certain times of the day, e.g. because of delivery time windows.

***Recommendation***
For these measures, use a dynamic assignment model (with a dynamic Origin-Destination matrix which the measure can alter), preferably with a multi-user class assignment.

## 8.5 Effect on destination / mode choice

***Explanation***

Examples of measures that influence the choice of destination or the choice of mode of transportation are: improved public transport, improved bicycle infrastructure, different spatial organisation (relocation of activities, e.g. schools, hospitals, shopping centres etc.). In some cases, closing a certain road or adding new infrastructure can also have an impact on destination and mode choice. In most cases, the measures have to be quite substantial for such effects to be noticeable.

***Recommendation***

Use a traffic model that can handle route choice. For improvements in public transport or bicycle infrastructure, a multimodal traffic model is needed that can handle mode choice. In most cases, this means that static macroscopic models are the most suitable.

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# ANNEX 1 GLOSSARY

## Traffic modelling

***continuum model***

Within a continuum model, vehicles are not treated as separate entities. The discrete nature of traffic is idealized to a homogeneous fluidum. Within this continuum approach traffic is described using typical variables from physics: density, intensity (also called the flow or flux) and the average speed. This results in a detailed description of traffic conditions in a space time lattice. The traffic density, the flow and the average speed are known along the road at each time step. Since no commercial packages exist, the use of this type of models is rather limited.

***demand model***

The traffic demand can be described in an origin–destination matrix (OD matrix), representing the number of persons that want to travel during a certain period between the origin and destination zones using a certain mode of transport. The demand model creates this OD matrix, based on the production of trips in geographical areas, the attractiveness of those areas and the effort needed to travel from one area to another (which is a derivative of the quality of the transport system). The OD matrix is input for the assignment models.

***diurnal pattern***

In meteorology, **diurnal** means daily, especially pertaining to actions which are completed in 24 hours and are repeated every 24 hours; this can be seen in the diurnal temperature variation[5].

***dynamic assignment model***

Traffic assignment is the process of allocating trips in one or more OD matrices to their routes (paths) in the network, resulting in flows on links. The assignment process is typically used to produce a number of indicators, not just flows. In contrast to static assignment, in dynamic assignment time steps (typically a quarter of an hour long) are used to calculate the level of flows per time step. Thus, an image of the development of the traffic loads can be given. Another advantage of dynamic models over static models is that they produce a more accurate location of traffic in congested situations, which can be important for noise calculations. On the other hand, dynamic models are more time consuming and need more input data than static models.

***intersection***[6]

A place where two roads meet.

[5] http://en.wikipedia.org/wiki/Diurnal
[6] http://en.wikipedia.org/wiki/Intersection

***link***

Part of the traffic network, generally representing a road. In the network visualization of macroscopic models, a link is usually represented as a straight line between two intersections.

***low flow road***

A road with a hourly traffic flow beneath a certain level. Important, because the correct prediction of the number of vehicles passing is often difficult.

***network***[7]

A transport network is typically a network of roads, streets, pipes, aqueducts, power lines, or nearly any structure which permits either vehicular movement or flow of some commodity.
A transport network is used for transport network analysis to determine the flow of vehicles (or people) through it within the field of transport engineering, typically using graph theory. It may combine different modes of transport, for example, walking and car to model multi-modal journeys.

***main road***

Important road which connects several parts of the agglomeration. Because of this connective quality, main roads often have high traffic flows.

***macroscopic / microscopic***

Macroscopic models describe the traffic in units of flow, whereas microscopic models consider each vehicle separately. Macroscopic models do faster calculations, and need less data than microscopic models. The visual outcome of microscopic models is at the other hand more attractive in some applications, because it is often possible to show the movement of individual vehicles.

***micro-simulation model***[8]

Microsimulation traffic models simulate the behaviour of individual vehicles within a predefined road network and are used to predict the likely impact of changes in traffic patterns resulting from proposed commercial developments or road schemes.

***modal split***

Distribution of trips over the transport modes. Sometimes use to indicate the share of trips using one particular model.

***model calibration***

Calibration refers to the process of setting the magnitude of the output (or response) of a measuring instrument to the magnitude of the input property or attribute within specified accuracy and precision[9]. The calibration of assignment models focuses usually on flows or speeds on traffic links. By adjusting, for instance, the travel time on links, it is possible to influence the calculation of traffic flows, so that it resembles the desired pattern.

[7] http://en.wikipedia.org/wiki/Transport_network
[8] http://en.wikipedia.org/wiki/Microsimulation
[9] http://en.wikipedia.org/wiki/Calibration

***MUC***

Multi User Class: technical term to indicate that the assignment model is able to distinguish several vehicle types in the calculation. With a MUC assignment, it is possible to predict the difference of results for different vehicle types. E.g. the number of trucks passing within an hour on a road.

***origin-destination (OD) matrix***

A matrix which describes the number of trips from each origin and destination in the studied area. These origins and destinations are typically grouped in so-called zones, which aggregate buildings and activities the produce and attract trips.

***peak hour***[10]

The time(s) of day when the highest volume of vehicles are typically encountered on a roadway.

***rerouting***

As a result of certain measures, traffic may be forced or motivated to choose a different route to travel from origin to destination: rerouting.

***road capacity***[11]

The volume of vehicles the road was designed to carry in a unit of time, such as an hour.

***static assignment model***

Traffic assignment is the process of allocating trips in one or more OD matrices to their routes (paths) in the network, resulting in flows on links. The assignment process is typically used to produce a number of indicators, not just flows. Static assignment methods are generally hour based: the origin-destination matrix contains for instance the trips of a peak hour. The capacities of the road network are expressed as number of vehicles per hour. As a result, the flows the assignment estimates are average flows per hour. With a static assignment, it is therefore not possible to get an insight on the development of a peak period. Consequently, these types of assignment are usually applied in long term policy studies.

***SUC***

Single User Class: technical term to indicate that the assignment model contains only one vehicle type. As a consequence, all vehicle types must be converted in to one average type: usually the passenger car unit. With a SUC assignment, it is not possible to get reliable result on flow of minority vehicle types, like trucks.

***traffic composition***

The types of vehicle a traffic flow consists of, and their shares. E.g. a traffic flow could consist of passenger cars (80%), trucks (15%) and motorcycles (5%).

[10] http://www.portlandonline.com/shared/cfm/image.cfm?id=85728

***traffic flow***

The number of vehicles that actually pass through a given road in a unit of time such as a day. Also called *intensity* or *flux.*

***traffic intensity***[11]

See traffic flow.

***traffic model***

A model that describes road traffic in a network given the distribution of inhabitants and jobs in areas, and the accessibility of these areas. In the application as meant in this report, traffic models typically deliver traffic loads and speeds on network links as a result. Normally, traffic models consist of a demand model (which creates the transport patterns) and a assignment model (which creates the network loads). There are, however, situations in which there is only a assignment model available, and the calculation uses a given demand. A disadvantage of this situation is that some measures that influence the transport demand cannot be calculated.

***trip***

A journey of a person of vehicle from a origin to a destination. In models, trips are stored in origin destination matrices.

***zone***

A geographical area which can be origins or destinations of trips.

<u>**Noise modelling**</u>

***acceleration / deceleration***

The change of vehicle speed per time unit, i.e. the derivative of speed in time. If the vehicle speed is decreasing, thus the vehicle is decelerating, the value of the acceleration will be negative. The negative value of the acceleration may then be called 'deceleration'. Unit: meters per square second ($m/s^2$).

***equivalent noise level ($L_{eq}$)***

Ten times the logarithm to the base 10 of the ratio of the time-average of the square of the sound pressure, $p$, during a stated time interval of duration $T$ (starting at $t_1$ and ending at $t_2$) to the square of a reference value, $p$0, expressed in decibels. The reference value, $p_0$, is 20 µPa.

***Harmonoise noise model***

The result from the Harmonoise project was a noise model for road and railway traffic noise, consisting of a separate source model for both these sources, and a propagation model to calculate the noise transfer from the source to any receiver point, including geometric and meteorological effects. The results from Harmonoise are adapted and further improved within the IMAGINE project, adding aircraft and industrial noise to the sources.

[11] http://www.berkshireplanning.org/3/1/

***Harmonoise road noise emission model***

Within Harmonoise WP 1.1, the road noise emission model was developed, which calculates the noise emission (i.e. the noise production at the source) of road vehicles, representative for the general European vehicle fleet. The model defines five vehicle classes, and calculates for each vehicle class the rolling noise and propulsion noise as a function of vehicle speed. Both noise sources are calculated as an instantaneous noise level, using the spot speed of the vehicle at a specific time, and combined and distributed over two source points directly above each other. A set of reference conditions and several correction factors, including meteorological conditions, road surface, and vehicle acceleration, for instance, are defined.

Within IMAGINE WP5, the model is adapted and improved, gathering data to fill the database of coefficients needed for the model. The source equations and point source definition remain the same; the vehicle category of “other heavy vehicles” will probably be removed.

See [Harmonoise, 2004] and [IMAGINE, 2006c] for details.

***heavy duty vehicle (HDV)*** or ***heavy vehicle***

A motor vehicle, possibly with (semi-)trailer, with 3 or more axles and a max. total vehicle weight of more than 3500 kg. These vehicles fall in category 3 of the noise model.

Examples: a rigid truck + trailer, a tractor + semitrailer, heavy buses with 3 axles.

***$L_{den}$, $L_{night}$***

$L_{den}$ and $L_{night}$ are the noise indicators proposed by the EU noise directive (END).

***$L_{W,line,eq}$***

The equivalent sound power level of a line source or traffic model link, per unit length. This is the total sound power produced by a traffic flow, which is constant over the link. Unit: decibel per meter (dB/m).

***light motor vehicle (LMV)***

A motor vehicle with two axles, four wheels, and a max. total vehicle weight of 3500 kg or less. These vehicles fall in category 1 of the noise model.

Examples: passenger cars, SUV, jeep, light vans.

***light / medium duty vehicle (LDV / MDV)*** or ***medium heavy vehicle***

A motor vehicle with two axles, > 4 wheels, and a max. total vehicle weight of more than 3500 kg. The terms LDV and MDV are more or less similar; a clear definition of the two is not given. For IMAGINE, both terms refer to the same vehicle category, 2, which is named “medium heavy vehicle”.

Examples: heavy vans with 2 tyre in front and 4 tyres on the rear axle, all trucks with 2 axles, buses with 2 axles.

***powered two-wheeler (PTW)***

A motorised vehicle with two (or three) wheels. These vehicles fall in category 4 of the noise model, which was category 5 in the Harmonoise model (see the future WP5 final deliverable D11 for details). The category also includes mopeds/scooters which usually have a speed limit of 45 km/h.

***propulsion noise***

All noise produced by the road vehicle that is not rolling noise or aerodynamic noise. The propulsion noise of a road vehicle is mainly generated by the engine, outlet, air inlet and gearbox.

***rolling noise***

The noise generated by the interaction between the tyres of the vehicle and the road surface, which is radiated by the tyres, vehicle and road surface itself. Within the IMAGINE model, the rolling noise source also includes all aerodynamic noise produced by the vehicle.

***sound exposure ($E_T$)***

Time integral of the square of the sound pressure, *p*, over a stated time interval of duration *T* (starting at *t*1 and ending at *t*2), or event:

$$E_T = \int_{t_0}^{t_1} p^2(t)\mathrm{d}t$$

Unit: pascal squared second, $\mathrm{Pa}^2\mathrm{s}$.

***sound exposure level ($L_E$ or SEL)***

Ten times the logarithm to the base 10 of the ratio of the sound exposure, $E_T$, to a reference value, *E*0, expressed in decibels:

$$L_E = 10 \cdot \lg\left(\frac{E_T}{E_0}\right)$$

The reference value, *E*0, is 400 $\mu\mathrm{Pa}^2\cdot\mathrm{s}$.

***sound power (W)***

Through a surface, the product of the sound pressure, *p*, and the normal component of the particle velocity, $u_n$, at a point on the surface, integrated over that surface. Unit: watt, W.

***sound power level***

Ten times the logarithm to the base 10 of the ratio of the sound power, *W*, to a reference value, *W*0, expressed in decibels.
The reference value, *W*0, is 1 pW.

***sound pressure (p)***

Difference between the instantaneous total pressure and the static pressure.
Unit: pascal [Pa]

***sound pressure level ($L_p$)***

Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, *p*, to the square of a reference value, *p*0, expressed in decibels (dB).
The reference value, $p_0$, is 20 µPa.

***vehicle speed***

The displacement of the vehicle per time unit. Unit: kilometres per hour (km/h) or meters per second (m/s).

***vehicle class*** or ***vehicle category***

One of the four vehicle classes of the IMAGINE road noise model: light motor vehicles, medium heavy vehicles, heavy vehicles and powered two-wheelers.

# ANNEX 2 CHECKLISTS

***<u>Checklist for the selection of a model</u>***

*What is the purpose of the exercise?*
- o Strategic mapping
- o Action planning

*What geographic area is to be covered?*
- o Main road network
- o Agglomeration

*What temporal period is to be used?*
- o The preceding year
- o Other: ………………

*What data is to be provided for the noise maps?*
- o Separate data for DEN and night-time maps
- o Only data for DEN maps

*Are weekdays to be treated separately to weekends?*
- o yes
- o no

*Are seasonal variations to be modelled?*
- o yes
- o no

*What parameters is the traffic model expected to provide as input for the noise model?*
- □ Flows (intensities)
- □ Speeds
- □ Speed distributions
- □ Accelerations
- □ More: …………………………..

*What user (vehicle) classes are to be considered?*[12]
- □ Passenger cars
- □ Medium heavy vehicles
- □ Heavy vehicles
- □ Powered two-wheelers
- □ More: …………………………..

*What other parameters are to be considered (because they are relevant for the network under consideration)?*
- □ Congestion modelling
- □ Intersection modelling
- □ Gradient effects

[12] See Harmonoise vehicle categorisation.

*In case of action planning: what effects are expected of measures?*

- □ Effects on the link level
- □ Effects on the network level (traffic reassignment effects / ‘rerouting’)
- □ Effects on departure time choice
- □ Effects on destination and mode choice

What spatial resolution of traffic data is required by the noise model? (Maximum link lengths? Points every ‘X’ metres?) Please describe:

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|---|
| |

What temporal resolution of traffic data is required by the noise model? (Hourly, day evening night periods?) Please describe:

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|---|
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What is the accuracy of traffic parameters; can their expected errors and uncertainties be quantified? Please describe:

| |
|---|
| *Flows:*<br><br>*Speeds:*<br><br>*Speed distributions:*<br><br>*Acceleration:* |

*How will outputs be handled?*

- o Directly into the acoustic software
- o Via other software, e.g. database or GIS system
- o Other: ………….

***Some of the above definitions may not be of great importance in strategic mapping, but may have influence on localised action plans or consideration of specific schemes.***

***All of the above definitions of scope should be used to ascertain an answer to the questions:***

*What type of traffic model is required?*
*Can an existing model (or models) already meet the above requirements?*

**→ Traffic model (type) chosen + motivation:**

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|---|
| *N.B. Consider that the choice of model depends on (a) a traffic model’s capabilities to produce the desired data, and (b) the traffic model and budget available* |

***Traffic modelling report***

*What type of traffic model is used?*

- o Static macroscopic model
- o Dynamic macroscopic model
- o Continuum model
- o Micro-simulation
- o other: …………………………..

*Is a multi-user class demand model / origin-destination matrix used?*

- o yes
- o no

*Is a multi-user class assignment model used?*

- o yes
- o no

*What user (vehicle) classes have been considered?*[13]

- □ Passenger cars
- □ Medium heavy vehicles
- □ Heavy vehicles
- □ Powered two-wheelers
- □ More: …………………………..

*What parameters does the traffic model provide as input for the noise model?*

- □ Flows (intensities)
- □ Speeds
- □ Speed distributions
- □ Acceleration
- □ More: …………………………..

***If an existing model is available, it is advisable to check:***

- *What was the model's original purpose?*
- *Are its limitations clearly known?*
- *Does complete documentation exist?*
- *Is access to the original software and input decks available to allow further model runs, or is the model 'output data only'?*

Please report relevant answers to these questions:

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|---|
| |

***If an existing model is available but does not fully meet the requirements, could it be cost-effectively supplemented to meet requirements?***

- *By extension of the network area?*
- *By modifications to the existing network area?*
- *By cordoning a sub-section of an existing network?*

[13] See also Harmonoise vehicle categorisation.

- *By extension of the coverage period or updating the base year?*
- *By updating O-D matrices or demand levels?*
- *By using a more detailed/different model for specific circumstances?*
- *By substituting in-situ detector data or in-vehicle data for specific circumstances?*

Please describe the possibilities for extensions/modifications:

***If the existing model can be extended spatially or is to be substantially updated, then collection of input data and calibration and validation data for the new areas will be required! If an existing model is to be cordoned then the calibration/validation of the sub-area(s) in question should be checked, and if necessary the models should be re-calibrated/validated.***

***If the existing model can be extended temporally then consideration must be given to:***

- *Can new calibration/validation data be collected for the new periods?*
- *If not, how are periods outside of those for which calibration and validation data are available are to be handled – specifically:*
    - *How are possibly limited time periods within a model converted to 24-hourly or period (day, evening and night) data?*
    - *How a model based on short-term data is scaled to represent annual data for the base year?*
    - *Do weekdays need to be modelled separately*
    - *How will the base year be scaled to long-term, 5-year data – what growth factors are to be used?*
    - *What are the potential errors and uncertainties involved in the above procedures?*
- *Should traffic reassignment be considered to model redistribution of traffic and its effects on speed and congestion?*

Please describe calibration and validation activities carried out:

***If there is no existing model then the following questions are considered:***

*Is it feasible to create a purpose built model to meet the stated requirements?*
*Can lower accuracy requirements be considered acceptable – allowing the construction of a simpler model?*

Please describe the possibilities for creating a purpose built traffic model, and what requirements can be met by this model:

***It is likely that compromises have to be made between what is desirable and what is achievable, e.g. in terms of modelled time periods and resolution of output data***

*For instance, the following situation might occur in practice for strategic noise mapping:*

- *A pre-existing traffic model, with some supplemental traffic data, will be available;*
- *It will be based on a macroscopic model;*
- *It will not meet the accuracy or resolution requirements of the acoustician;*
- *Further data and model runs will therefore be necessary;*
- *Some compromise may have to be made regarding the total number of modelled time periods and output resolution etc. between what is desirable and what is achievable.*

Please describe the compromises made in the process of traffic modelling for noise mapping and noise action planning:

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|---|
| |

***If a standard modelling report, like a Model Validation Report (MVR) or a Model Forecasting Report, is available, please include it in the documentation of the modelling process.***

# ANNEX 3 TASK REPORTS 2.1-2.4

The technical reports produced in work package 2 of the IMAGINE project serve as annexes to this report. Background information on the guidelines can be found in these reports.

The following technical reports are available from the IMAGINE-website at www.imagine-project.org (see the section on work package 2 in the 'topics' section):

| Task | Title | Document identity |
|---|---|---|
| 2.1 | Review of data needs for road noise source modelling | IMA2TR-040615-M+P10 |
| 2.2 | Review of the suitability of traffic models for noise modelling | IMA02TR-050112-TML10 |
| 2.3 | Development of strategies for the use of traffic models for noise mapping and action planning | IMA2TR-060131-UGENT10 |
| 2.4 | Collection Methods for Additional Data | IMA02TR-060525-UL10 |

Below, the executive summaries and complete references of the reports are given.

**R2.1 - Review of data needs for road noise source modelling**
*Author: Bert Peeters, M+P. Document identity IMA2TR-040615-M+P10*

Executive summary
The calculation of noise maps requires a noise source model for road vehicles, a network traffic model, and a sound propagation model. The output data from the traffic model are input to the noise source model, which should then provide the yearly averaged noise emission levels for each period (day, evening and night). The main purpose of this report is to identify the data needs for the calculation of road noise emission, i.e. which parameters are input to the noise source model and what should thus be the output parameters of the traffic flow model?

In order to describe this, the road noise source model is analysed and its data needs are identified and set off against the data that is provided by four types of traffic models. As the four traffic model types vary in complexity and level of detail in output data (intensities, speeds), four different methods of calculations for the aggregation from single vehicle to traffic flow are proposed. These four methods have been applied in some typical (theoretical) traffic situations, to see how the outcomes vary according to level of detail of the data (i.e. what is the added value of more detailed traffic data). Also, the sensitivity of the noise source model to variations in traffic parameters (intensity, speed, acceleration, traffic composition) has been explored, in order to establish which traffic parameters should be modelled most accurately

With respect to the various levels of detail available, it may be concluded that the minimum amount of information to allow calculation of the sound power level of a certain road segment is the traffic intensity and the average vehicle speed for each of the main vehicle categories for each period of day. The accuracy and representativeness of the results will be further enhanced if the distribution of vehicle speeds and acceleration values are included. The highest level of detail is to have the vehicle category, speed and acceleration for each vehicle at each road segment.

In general, situations with low vehicle speeds and high acceleration values demand more detailed information. It is concluded that for a motorway situation, using only the traffic intensity and

average speed results in a minor error, which may be improved by the inclusion of a (rough) speed distribution. For an urban 50 km/h road situation, the inclusion of a distribution of acceleration values is necessary for an acceptably accurate result. For the modelling of a road intersection, neglecting acceleration altogether causes a large error; the use of individual vehicle data is necessary to assess the overall noise level with an acceptable error. As intersections are not always modelled separately in traffic models, corrections factors may have to be derived for different types of intersections.

With respect to the sensitivity of the noise source model for the various traffic parameters, it may be concluded that the noise model is less sensitive to variations in the total vehicle intensity than to the percentage of heavy motor vehicles (HMV) and the average vehicle speed. Furthermore, the inclusion of a vehicle speed and/or acceleration distribution may have a significant positive influence on the results, but the resolution of these distributions does not seem to be very important.

The work in tasks 2.2 and 2.3 should focus on the accuracy of the traffic model output data and its consequences for the calculated noise levels. Furthermore, the details of the aggregation from single vehicle instantaneous noise levels to a larger traffic flow should be investigated.

**R2.2 Review of the suitability of traffic models for noise modelling**
*Authors: TML, TNO, University of Gent and University of Leeds. Document identity IMA02TR-050112-TML10*

<u>Executive summary</u>
The development of noise maps requires the extraction of relevant traffic information from traffic models. The intrinsic properties of traffic models and the current and future practice in traffic modelling are reviewed in this report.

A classification is made of existing traffic models along with an overview of the kind of output they can deliver. Furthermore, the required input for the different model types is discussed. The discussion of the linkage of traffic models with noise source models is based on the experience within the consortium.
A preliminary assessment of the Strengths, Weaknesses, Opportunities and Threats was made for the suitability of the different types of traffic models to deliver input for noise models. The interactive workshop with traffic model developers resulted in the refinement of these SWOT-analyses.

It can be concluded that current traffic models, in their various forms, can be used to produce the data needed for noise modelling, but the link between traffic models and noise models is not unambiguous. There are several weak points in traffic models that need attention:
- the consequences of intrinsic model characteristics (with regard to the input data used, the modelling technique and the output produced);
- problems associated with the use of traffic models in practice;
- problems associated with interfacing between traffic and noise models;
- the quality of data for the traffic demand and assignment models, and how this relates to accuracy;
- the effort involved in building, calibrating and maintaining the model;
- the modelling of possible noise reducing measures;
- additional indicators for the assessment of quiet areas and night-time noise.

These caveats arise, because traffic models were originally developed to evaluate transportation policies. It is (also) possible to use traffic models for environmental policies, but usually this requires modifications both to the models and their input.

Improving current traffic models to fulfil the input needs of noise models will require some effort. The formulated recommendations focus on the directions for the development of pragmatic guidelines for the link between traffic and noise within Work package 2 of IMAGINE.

**R2.3 Development of strategies for the use of traffic models for noise mapping and action planning**

*Authors: University of Gent, TNO, TML, University of Leeds, M+P and Leicester City Council. Document identity IMA2TR-060131-UGENT10*

Executive summary

A first part of this report continues the efforts made in Task 2.1 to quantify the accuracy goals for traffic parameters, in order to produce noise maps with a well-defined accuracy. The accuracy demands depend on the magnitude of the traffic parameters, and simple criteria on individual parameters are therefore not always sufficient. Hence, this report focuses on combined effects and accuracy issues in a realistic context. Based on case-studies, traffic intensity, traffic speed and traffic composition on the major roads seemed to be of first importance for strategic noise mapping purposes for major roads. For noise mapping of urban roads, the use of acceleration and deceleration data, in addition to the firstly mentioned traffic parameters, lead to further improvements. Correction factors can be used in case the traffic model is not capable to provide this data. The importance of low flow roads in urban context depends on the required accuracy at lower exposure levels. Further improvements in the accuracy of noise mapping of both major and urban roads may come from including speed distribution, and from accounting for long term (or diurnal) variations in flow patterns.

It is often hard to obtain the needed accuracy with common traffic models, even for the traffic parameters that are of first importance. Therefore, some major shortcomings are addressed, and some guidance is provided to improve the traffic model outcomes. Recommendations and references to dedicated literature are provided specifically for demand modelling, traffic composition modelling, intersection modelling and the problem of low flow roads. Modelled speed is treated briefly. Taken into account its large influence on the accuracy of the noise map, and the problems involved (or lack of information on its accuracy) with traffic modelling, this will be an important issue to be covered in task 2.4 on additional data collection.

**R2.4 Collection Methods for Additional Data**

*Authors: Paul Goodman, Phillip Skelton, University of Leeds. Document identity IMA02TR-060525-UL10*

Executive summary

The deliverable of task 2.4 of the IMAGINE project deals with the issue of collecting data for the effective modelling of noise from road traffic using the new HARMONOISE vehicle source model. Previous tasks of IMAGINE work package 2 have identified a range of issues where the collection of supplemental information could considerably enhance the use of traffic models.

The document is divided into a number of complimentary sections. Initially the previous IMAGINE WP2 deliverables are reviewed to draw out the most pertinent data issues – notably the handling of demand within traffic models, the treatment of vehicle speed and acceleration, the classification of vehicles, treatment of intersections, low flow roads in agglomerations and additional requirements for successful traffic micro-simulation. Some discussion is then provided regarding current and best practice in traffic modelling, in order to ‘set the scene’ for data collection.

The bulk of the document is concerned with the use of a diverse range of in-situ or in-vehicle detector systems. Based on a literature review current, and potential future technologies are discussed. Focus is given to the accuracy of these systems in providing the main parameters required for noise modelling – flow, speed and composition, though, where appropriate other parameters are discussed.
From the review it has been concluded that Inductive Detector Loops (IDLs) are the current, de-facto standard for in-situ detectors, and may be expected to provide a considerable volume of information for mapping. Other technologies, whilst not yet routinely deployed, provide comparable performance to IDLs. Almost all reviewed technologies may prove adequate for noise modelling purposes – with some minor caveats regarding deployment location, performance in inclement weather conditions and cost of operation. The use of video techniques and fusion of multiple sensors are exciting and rapidly developing areas. Regarding in-vehicle systems, the operations of commercial service providers and continuing advancements of satellite tracking technologies offer the possibilities of collecting journey information across extensive areas of the continent. Case studies, using data from a limited number of systems to provide noise emissions predictions have been provided in the text.

There is a growing trend for traffic (and other) information from both main roads and in agglomerations to be collated, processed and stored in unified databases. These databases are housed at Traffic Management Centres (TMCs) or Urban Traffic Control Centres (UTCs) and offer analysis of long-term traffic patterns, and the potential for continual validation of mapping exercise results.
Finally, it is recognised that, by the time the HARMONOISE methods are first used in practice, considerable experience will have been developed in handling large volumes of traffic information from the interim round of mapping (2007). This experience will add to knowledge gained through the continued operation of air-quality management systems and supplement additional traffic information published by relevant authorities or agencies. All of these may prove invaluable to future practitioners.