State of the art of noise mapping in Europe

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2 EXECUTIVE SUMMARY

The Directive 2002/49/EC on the assessment and management of environmental noise (END) requests the competent authorities in the Member States to produce noise maps of the main agglomerations before the 18th of July 2007.

Examples of how municipalities, regions and Member States have produced noise maps in the past and how they are adapting to the new requirements of the END are gathered in the present report. This information has been provided on a voluntary basis from various noise-mapping experts in a selected number of case study cities, regions and countries in Europe and has also been collected from information published on the web.

Focus is given to selected aspects of the noise mapping process: collection of noise emission, noise propagation and noise immission data, calculation method used, maps and indicators produced and, finally, main problems encountered and lessons learnt from the experience.

The information provided for the report was very heterogeneous in amount and quality and, therefore, comparisons among case studies are not easy. However, solutions found to common data problems described in the report can be of help for other noise-mapping experts.

Road traffic is mapped in every case study, followed in importance by railway traffic. Aircraft and industrial noise are only specifically mapped in four case studies.

The degree of availability of detailed and accurate data needed to set up noise maps varies depending on the case study. The lack of data is solved either by creating a new dataset especially for the mapping activity, by extrapolating the existing average data to other situations or by introducing a number of general assumptions. The latest is the case, for instance, for many of the meteorological data.

Whilst most of the case studies have used, as recommended by the END, modelling tools to produce their noise maps, three case studies (Cyprus, Madrid and Prague) have used regular direct measurements.

All case studies consider road traffic as the main source of noise to be mapped. Railway is the second most commonly mapped noise source. Noise data from airports and industry are specifically collected in only four of the case studies.

In a very synthetic way it can be said that data acquisition of emission data sources are mainly local authorities, except for railway and aircraft data. Propagation data involves more heterogeneous information sources, including the creation of additional datasets. Building heights and distribution of population by building are among the most difficult data to be obtained.

The report illustrates a wide variety of situations and shows how noise-mapping experts have managed the problems encountered.

Most commonly used indicators were Lden. Indicators on exposed population are presented to the public in only few case studies. In many situations indicator had to be converted from the old measurements to Lden. Most commonly used maps present noise immission contour maps or grids, both separately by source as well as all sources together. Municipalities that use measurements only show total immission maps, as they do not track the sources.

Common complaints found in almost every case study are, first, that the process of data collection, production and treatment is time and cost consuming and secondly, the there is generally speaking lack of data.

3 INTRODUCTION

3.1 THE 2002/49/EC ENVIRONMENTAL NOISE DIRECTIVE

The 2002/49/EC Environmental Noise Directive (END) is based on three main principles: harmonisation (noise indicators, noise evaluation, calculation methods, measurement methods, monitoring, strategy, and legislation), collecting of information on noise in the form of noise maps, and informing the public on the current noise situation and on strategy and financing of noise reduction.

The END aims at determining exposure to noise through strategic noise mapping by using noise indicators and assessment methods common to Member States. In order to measure the various levels of acoustic pollution that European citizens are suffering, the Directive requests the competent authorities in the Member States to produce noise maps of the main agglomerations. This information must be ready before the 18th of July 2007.

Noise mapping is not a new activity. Noise maps have been produced in many countries of the European community since the 1970-ies. However, the Directive 2002/49/EC on the assessment and management of environmental noise (END) is the first attempt at European level to harmonise the procedures of noise mapping at European level and establish an important degree of citizen protection against environmental noise.

3.2 BACKGROUND ON NOISE MAPPING ACTIVITIES IN EUROPE

Some comprehensive reports have been written in the context of noise mapping at European level. One of them was carried out by the UK Department for Environment, Food and Rural Affairs (DEFRA) "Noise Climate Assessment: A Review of National and European Practices". The report covers aspects of noise legislation in several European countries and the existence of noise mapping initiatives at national, regional and local level.

Another example is the report "IMAGINE –State of the art", which is a deliverable of the

IMAGINE project (Improved Methods for the Assessment of the Generic Impact of Noise in the Environment). This gives an overview of the experience gathered in the different countries with respect to the production of noise maps. The IMAGINE project is closely linked to the HARMONOISE project, in which harmonised computation methods are developed.

Other important sources of information on noise mapping methodologies are the conclusions resulting from the European Commission Working Groups, for instance, the "Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure" produced by the Working Group on Assessment of Exposure to Noise.

Among other activities on urban sustainability, the European Environment Agency (EEA) is currently working on a proposal for streamlining data collection and mapping of noise in EU cities. In parallel to this activity, the European Topic Centre on Terrestrial Environment (ETC/TE) contributes to the noise topic with the present report. Previous EEA work regarding noise issues includes reports on the preparation of the new EU Noise Policy (http://reports.eea.eu.int/NOS01/en/eu_noise.pdf) and a report on the progress of the results of the Working Group 3 on "Noise Computation and Measurement", published in September 1999.

3.3 OBJECTIVES

Among all the steps that noise mapping involves, from the transposition of the END to Member States' legislation, to the final editing of the noise maps, the present report focuses on selected aspects that can be answered by the following questions:

- What methods are used to produce noise maps: measurements, modelling, or a mixture of both?
- If direct measurements are undertaken, what technology is used, how are the results integrated in the noise maps?
- If modelling tools are used, what input data (noise emission data, noise propagation data and noise immission data) need to be acquired, where are data obtained from and in which format? What models are run?
- What indicators and maps are being produced?
- What have been the main problems encountered and lessons learnt during the noise mapping process?

The way to approach these questions has been through direct contacts and case studies in various cities, regions and countries. Valuable information was provided by the voluntary collaboration of noise mapping experts in various municipalities, ministries and private institutions. In addition, a great amount of reports, maps and additional information has been extracted from the web.

3.4 NOISE MAPPING PROCESS

Responsible authorities for noise mapping go through a process that starts with the design of the noise mapping process, including the choice of the method – real measurements, modelling or a combination of both – and the identification of the datasets and ends up with the calculation of immission noise levels (noise contours, noise grids, etc.) or/and the final indicator required by the END, the number of exposed population to annoying levels of noise.

If modelling is chosen, a wide range of data needs to be collected. These can be conceptually divided into data from noise sources or emission data, noise propagation data, and noise immission or nuisance data. Depending on the model the data specifications and level of detail will vary (see figure below).
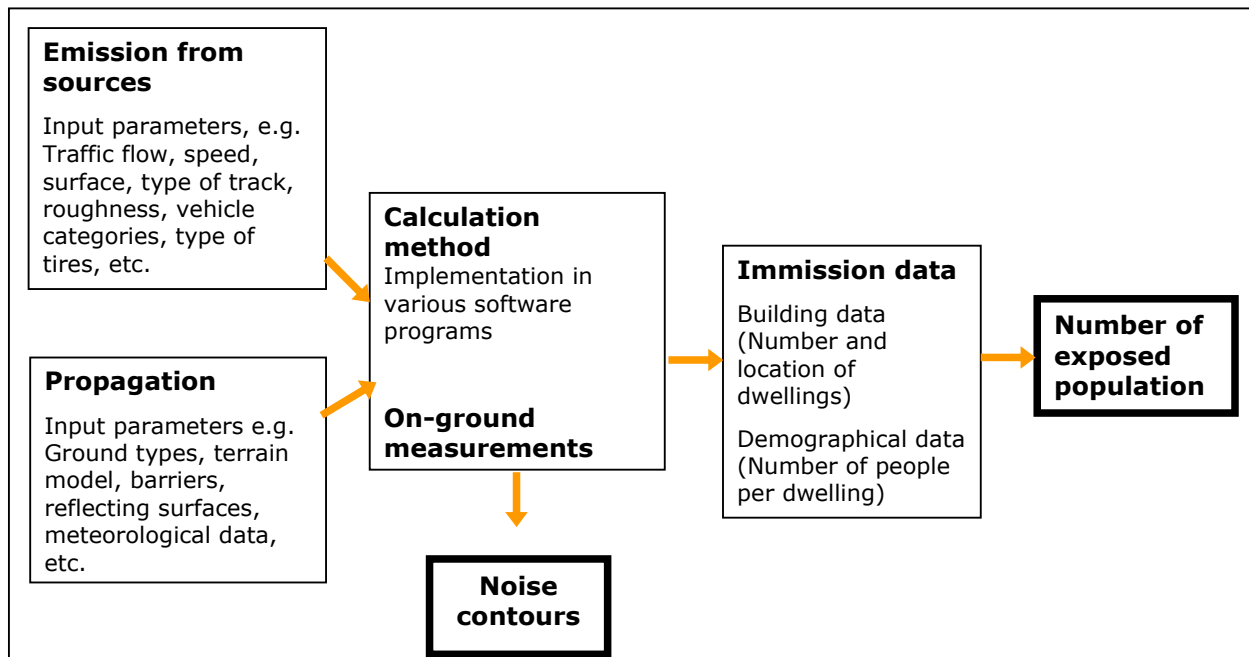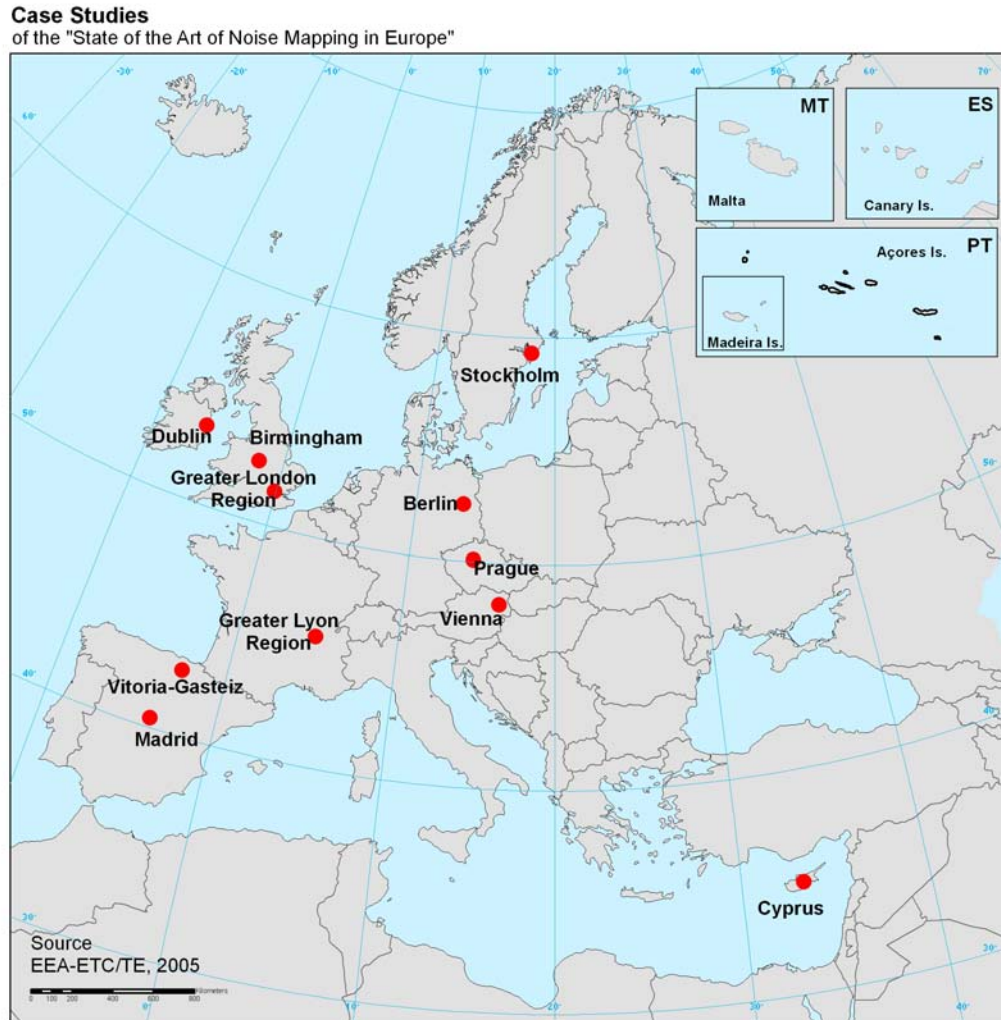

Figure 1 – Conceptual scheme of the noise-mapping process through modelling

3.5 CASE STUDIES

In total eight cities, two regions and one country have been included as case studies in the report (see map below).

Case Studies
of the "State of the Art of Noise Mapping in Europe"

4 BERLIN CASE STUDY

4.1 INTRODUCTION

The information for the Berlin case study was mainly obtained from the Environmental Atlas in the website of the Senat Department of Urban Development (see references).

Noise responsibles at the municipality of Berlin were contacted for the section on Problems encountered and lessons learnt.

4.2 NOISE EMISSION DATA

4.2.1 Road Traffic data

The Berlin road network extends over a total of approx. 5,140 km. Traffic noise levels are certified for 1,302 km of this total area. This selected area includes as a rule the main traffic routes; the inner-city area, all streets with speed limits of 50 km/h; and also the entire tram network.

The traffic-noise map "Main Road Network" portrays the calculated daytime (0600 to 2200) and nighttime (2200 to 0600) assessment levels. The calculations were carried out according to the technical guideline RLS 90 (Guidelines for Noise Prevention on Roads, 1990 Edition), which is applicable nationwide.

The applicable limit, target and orientation values are aimed at a comparison with evaluation levels. The evaluation level is obtained from the assessment levels obtained in the traffic noise map by addition of correction factors, which take into account break and start-up noise in the neighbourhood of traffic signals. These correction factors are to be added as follows: for distances of up to 40 m, +3 dB; for distances between 40 and 70 m, +2 dB; and for distances between 70 m and 100 m, +1 dB.

The basis of the calculations is the average daily traffic volume (DTV) of a route section. This value, which was determined in 1998 on the basis of extensive traffic surveys, takes into account seasonal fluctuations share of truck traffic in the overall traffic volume.

The number of municipal public transport system buses was incorporated on the basis of the BVG's (Berliner Verkehrs Gesellschaft) winter 2001 schedule.

4.2.1.1 Tram data

The entire tram network was also incorporated into the Traffic Noise Map. The evaluation level for tram traffic was calculated according to SCHALL 03 (the calculation regulation for rail-traffic noise) on the basis of the 2001 winter schedule (including non-service trips). According to the SCHALL 03 stipulations, the evaluation level was ascertained by subtracting the "rail bonus" of 5 dB from the assessment level of trams. The rail bonus is allocated due to the lower burdensomeness of rail traffic compared to vehicular traffic.

Among other things, the calculation takes into account the building situation as well as the type of track bed (e.g., gravel bed or rail flush with the roadway), not however particular types of tram trains (Tatra trains, low-body trains, etc.). Evaluation levels are calculated for every track section-side for both daytime and nighttime.

For street sections affected by motor vehicle and tram noise, the total level is represented in the map.
In addition to the levels for the roadside buildings, standardised assessment level (motor vehicles) or evaluation level (tram) at 25 m distance from the respective outer right lane is stated, particularly for planning purposes. Any existing reflective buildings are not taken into account for the calculation of this level. If the required resulting air sound

absorption of external structural components is to be determined on the basis of an evaluation level as per DIN 4109 obtained from the file (i.e., for determining the dimensions of windows), the "applicable external noise level" required for that purpose is obtained by adding a correction factor of 3 dB to the evaluation level.

For the presentation of the map in the Internet, the road sections of the counting network were assigned to the block sides of the digital map 1:5000 (Digk 5) facing the street. Block corners strongly angled to intersections were assigned only when a clear assignment to one side of a street was possible.

4.2.2 Railway data

The railway traffic noise map covers the 246 km long aboveground main line, S-Bahn[1] and subway (U-Bahn) network (in many cases, jointly-used routes). Station areas, loading areas for goods, and track junctions were not considered, due to unusual features that the calculation model does not cover.

The bases for the calculation are operational data of the German Railway (Deutsche Bahn AG) and the BVG, based on the 2003-'04 winter schedule.

The evaluation levels at the respectively nearest buildings were ascertained according to SCHALL 03, the nationally applicable regulation for railroad traffic noise calculation. In order to have a very detailed ascertainment of the basic data needed for the calculation, the network was divided into 1,586 sections. All required values - number of trains per type of train, speeds, types and distances of buildings, types of track body, bridges, radii of curves, etc.- were ascertained specifically for each section side. As with trams, the evaluation level incorporated the "rail bonus" allocated under SCHALL 03 (discount of 5 dB of interference, due to the lesser burdensomeness of railroad traffic in comparison with vehicular traffic).

4.3 NOISE PROPAGATION DATA

The building parameters – such as distance of the buildings from the roadway; types of buildings (open; closed); heights and types of the building facades (smooth or structured) - were obtained from the "Automated Berlin Real Estate Map, 2001" (ALK).

The parameters related to roads - structure of the road surface, location of the road in a depression or on an embankment, the presence of noise safeguards (walls; embankments) the amount of the available lanes, the allowed maximum speed - were actualised in autumn 2003 by driving along the whole network.

In order to allow the inclusion of the above-mentioned parameters as exactly as possible, the 1,302 km of the main road network that were examined, were divided into 7,494 sections. The typical features were then ascertained and roadside-referenced for each section. This also applies to the important amount of data on "building distance". For route sections with protruding or recessed structures, the building distance was as a rule calculated on each side in the section for the most frequently occurring distance between the buildings and the middle line of the road. For buildings with a considerably varying distance, a distance correction factor must be incorporated (rule of thumb: doubling/halving of the distance means a decrease/increase corresponding to 3 dB).

A standardized evaluation level in 25 m of distance was calculated for the respectively outer right track (without consideration of buildings) in addition to the daytime or nighttime overall evaluation level of the buildings of the respective section-side, for planning purposes.

Inevitably, the noise maps themselves contain only a part of the existing data in their

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[1] S-Bahn is an overground urban railway system in Berlin

cartographical sections. E.g., it is not possible, at the scale 1: 50,000, to correctly represent the effect of traffic signals, which is necessary for the establishment of the evaluation level. Under RLS 90 correction factors of 1 to 3 dB could be provided up to a distance of 100 m. This would yield the evaluation level for which the above-mentioned orientation or limit values apply. In the other areas, the evaluation level equals the assessment level represented.

4.4 INDICATORS AND MAPS

The level classes represented in the Noise Map, with a class width of 5 dB (A) show the noise immissions at 3.5 m above ground, in front of the building facades affected by the traffic noise, at a distance representative of the respective road section, between the building facade and the nearest lane axis (see annex 4.4).

However, in the present new version of the Noise Maps, a possibility was created for obtaining even more detailed information about the selected section, by means of the expansion of the data indication. In addition to the code number of the section, from which further information can be assigned from the traffic noise register from the Senate Department of Urban development, it also contains the following parameters:

- Designation of the borough in which the section is located;
- Street name;
- Assigned Statistical Block;
- DTV for motor vehicles and trucks, right and left sides of the street ascertained separately;
- Number of BVG busses, day and night, right and left sides of the street ascertained separately;
- Number of trams day and night, right and left sides of the street ascertained separately;
- Distance from roadway centre line to building, right;
- Distance from roadway centre line to building, left;
- Distance from tram centre axis to building, right;
- Distance from tram centre axis to building, left;
- Overall assessment level at buildings; right and left sides of the street ascertained separately;

For the area of railway traffic:

- Name of the station, for sections which correspond to a station;
- On the route from ....;
- On the route to ....;
- Designation of the borough in which the section is located;
- Overall assessment level at buildings; right and left sides ascertained separately;
- 25 m overall assessment level at buildings; right and left sides ascertained separately.

4.5 LESSON LEARNT

According to noise experts in the municipality of Berlin, the most difficult and expensive part of noise calculation was the collection and treatment of all needed data (geographical, geometrical, technical, traffic counts for day and night).
The buildings heights were not available and had to be estimated from the number of floors. Traffic count data we obtained only as average for 24 hours, not for day and night period. Because of the large scale of calculations the simplified model "long straight segment" was chosen and noise traffic was calculated only for facades by the roadside.

5 BIRMINGHAM CASE STUDY

5.1 INTRODUCTION

Birmingham is the second largest city in the United Kingdom, with approximately 1 million inhabitants and with and extension of 330 square kilometres. Birmingham is at the centre of the UK motorway network and has rail communications to all major UK cities.

The overall project objective for the Birmingham Environmental Services Department (BESD) was to produce 'state of the art' noise maps of the City of Birmingham in sufficient detail to allow them, after further development, to serve as a strategic planning and noise reduction tool and as an aid for day to day decision making on many environmental noise matters.

A general scheme of the work done to produce noise maps in Birmingham can be found in annex 5.6.

5.2 NOISE EMISSION DATA

5.2.1 Road Traffic Data

The BESD obtained Road traffic data from the Joint Data Team (JDT)[2], who extracted the information from the West Midlands Traffic Model.

In total 880 kilometres of road and motorway inside and just outside the Birmingham City boundary were identified as having two-way, 24 hour traffic flows of more than 2,000 vehicles per normal weekday.

These 880 kilometres are divided up into 1,900 separate road sections in the data supplied by JDT. For each of these road sections, separate traffic flow (24 hour, 2 way), speed and Heavy Goods Vehicles (HGV) content data was supplied to the consultant in EXCEL spreadsheet format. In addition similar data was also supplied for the M5 motorway, which skirts the western side of the City boundary. The road traffic data supplied by JDT was not independently validated.

Roads are divided into 4 classes (see table below).

	Kind of road/motorway	Percentage of flow during daytime (0700 to 2300)
Class 1	Dual carriageways	93.0
Class 2	A roads	93.0%
Class 3	B roads	94.7%
Class 4	Unclassified, including city centre roads.	roads 94.8%
Motorways		91.7%[3]

Figure 2 - Percentage of flow during daytime

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[2] The Joint Data Team is a consultant specialised in services in the handling of information comprising collection of data related to travel, land use and population characteristics.

[3] flow between 0600 and 2200 hours. The percentage for 0700 to 2300 hours was assumed to be the same.

Modelled speeds were based on journey times, not on measured speeds. Comparison with available measured speed data suggested that the actual speeds on free flowing sections of road were, on average, around 30% higher than the modelled journey time speed. Therefore, a universal correction of plus 30% was applied to all modelled speeds up to a maximum of 5 mph/8 km/h above the road speed limit.

The road traffic data supplied by JDT was used to identify the speed, flow and composition % Heavy Good Vehicles (HGV) on each of the 1,900 individual road sections in that part of the West Midlands.

Because no separate data were available it was assumed that the composition (% HGV) on roads and motorways was the same for both daytime and nighttime.

For the same reason the speed of the traffic was assumed to be the same for the daytime and nighttime. A further assumption was that all road and motorway surfaces were constructed of impervious bitumen with a texture depth of 0.98 millimetres.

There were no speed data for the 'City Centre' roads. The speeds were taken to be 30 mph (50 km/h) day and night.

For the purposes of the calculation, LIMA subdivided the 1900 individual road sections, which equate to some 880 kilometres of road, into 20,880 individual segments. The gradients of each of these segments were derived from the Ordnance Survey Landform

Panorama Data. Gradients of more than 6% were identified as being 6% (in accordance with CRTN.

For each road segment, the data supplied was used to calculate the LA10 noise level at 25 metres from the source using the procedure given in CRTN.

The data on the noise level at 25 metres was used in LIMA to obtain the sound power level/metre (LWA/m) of each road segment, as required by the sound propagation model used in LIMA. For this purpose LIMA used the procedures from the German standard for road traffic noise, RLS90 (13). This standard works in terms of LAeq. Therefore, the consultants derived a relationship between this indicator and the LA10 values obtained from CRTN at a distance of 25 metres. Previous research carried out by the consultant and the results from the noise measurement exercises carried out at Walmley Golf Club and Sutton Park in Birmingham were used as the basis for deriving this. The relationship is shown below:

If P≤30 LAeq = LA10 − 3.6 (30−P)/30

If P>30 LAeq = LA10

where P is the percentage of HGVs (vehicles > 3 tonnes).

5.2.2 Railway Data

Information on the number of normal weekday day and night-time passenger train movements was also supplied to BESD by JDT.

Those data, which were not independently validated, included information on the type, length and speed of trains.

The data on goods train movements was obtained from Railtrack plc. These data included the typical number of goods train movements during an average weekday on rail lines in the Birmingham area and the types of locomotive used for these movements. It was assumed that the average length for goods train was 500 metres and that the average speed was 64 to 80 kph. The gradient of all rail tracks was taken as zero as there were no significant gradients on any of the tracks in the Birmingham area. All rail tracks in Birmingham are taken as continuous welded rail (CWR). All electric trains were assumed to be made up from BR MK1 tread braked carriages. All diesel passenger trains were

assumed to be hauled by diesel locomotives on full power. All freight locomotives were taken to be class 56 on full power.

For the purposes of calculation, LIMA subdivided the 131 kilometres of railway line, which were included in the model, into 869 separate segments.

For each rail segment the data supplied was used to calculate the noise level at 25 metres from the source using the procedures given in CRN.

The data on the noise levels at 25 metres was used in LIMA to obtain the sound power level/metre (LWA/m) of each rail segment as required by the sound propagation model used in LIMA. For this purpose, LIMA used the German guideline for the calculation of railway noise, Schall 03(14).

Investigations carried out by the consultant indicated that, under unobstructed propagation conditions, and up to a distance of 2000 metres from the source, the results produced by the British CRN method (11) and the German Schall method (14) were virtually identical when the standard air absorption coefficient _ in the Schall method was changed from 1/200 to 1/140. For the final rail noise calculations Schall was used with _ taken to be 1/140. (see consultant's report (12)).

When sound immission calculations were carried out, a better correlation between calculated and measured train noise levels was obtained when the speed of goods vehicles was assumed to be 60 kph rather than the 64 to 80 kph as suggested by Railtrack plc. Therefore, 60 kph was adopted for the final rail noise calculations.

5.2.3 Aircraft Data

Consultants produced sound immission contours for the Birmingham International Airport (using the CAA Aircraft Noise Contour Model. Data used was from 1998 and included daytime (0700 to 2300 hours) and night-time (2300 to 0600 hours) periods[4].

Data were obtained by BESD from the Airport in AutoCAD DXF format and forwarded to the mapping consultants. The contours are in 3dB bandwidths spanning the range 54 to 72dB LAeq(16hr) for daytime and 48 to 72dB LAeq(7hr) for night-time.

Birmingham Airport flight data for May and June 1998 showed time of flights, type of aircraft and runway usage. It was supplied to BESD by Birmingham International Airport plc, in EXCEL spreadsheet format.

The noise contours supplied by Birmingham Airport plc for day and night are in 3dB steps (see Appendix 11). The consultants developed a procedure to 'convert' this information into the 5dB steps necessary for the mapping project. This procedure is best explained by way of the following example:

In the case of the 5dB contour band between 60 and 65dBA, the area between 60 and 63dBA in the data supplied was set to 61dBA whilst the area between the 63 and 66dBA contour was set to 64dBA. Therefore, both of the original 3dB contours now fall into one 5dB contour. This procedure was not endorsed by BESD before implementation.

7.4.2 For the production of the night-time aircraft noise maps the 2300 to 0600 hours LAeq(T) contours provided by Airport were used as supplied. No attempt was made to estimate the LAeq(T) for the 2300 to 0700 hours period.

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[4] The period 0600 to 0700 hours is considered by Birmingham International Airport to be a 'shoulder period' between night and day, and is not usually included in any day or night-time noise contour calculations. No attempt was made to estimate the noise level over this period.

5.2.4 Industry Data

In total 21 industrial premises were selected for inclusion in this phase of the mapping exercise. These sites were chosen because they include some of the largest industrial complexes in the City and generally have some history of environmental noise concerns.

Time constraints did not permit the inclusion of any other additional industrial premises at this stage. All of the 21 sites were visited and noise measurements were taken jointly by deBAKOM and BESD at 16 of them. At the remaining 5 sites the ambient noise levels from road traffic were judged to be well in excess of that from the industrial premises in question. The noise levels from these industrial sites were taken to be 10dB below the ambient road traffic noise levels calculated by the LIMA software for these sites.

From the noise levels measured at each industrial location the consultants calculated the sound power levels of the industrial sources. For calculation of sound immission contours, these sound power levels were distributed along the facades and roofs of the industrial buildings (see consultant's report (12)). The distribution of sound power levels was 'adjusted' so that the sound immission levels calculated by LIMA, through the propagation model, matched those produced at the measurement locations, as closely as possible.

The nighttime industrial noise contours were produced by assuming that only part of the plant would be operating at night. As a 'rule of thumb' correction the daytime sound powers were reduced by 90%.

5.3 NOISE PROPAGATION DATA

5.3.1 Geographical Data

The following geographical data was obtained by BESD from, or through, Birmingham's Economic Development Department (EDD):

- Ordnance Survey Landline digital map data consisting of 1,360 tiles (to cover

- all of Birmingham and immediate surrounds). Each tile covers an area of 500 metres by 500 metres, shows all buildings, roads, rail lines and public open spaces.

- Ordnance Survey Landform Panorama digital height contours in 9 separate tiles

- covering all of Birmingham.

- Ordnance Survey 'OSCAR' (Centre Alignment of Road) digital data.

- A 1:50,000 scale Bitmap of the City.

- Digital data of Birmingham's boundary location.

With the exception of the Bitmap, all the information mentioned above was originally obtained in National Transfer Format (NTF). At present LIMA Mapping Software cannot recognise information in this format. Therefore, it was necessary to translate this data into AutoCAD, 'DXF' data format. For the Landline and OSCAR data, this translation was carried out 'in-house', by EDD using 'Cartology' software. It was found that this software could not satisfactorily convert the Landform Panorama data. However, as a result of further enquiries, the Ordnance Survey supplied this data in the required format.

Aerial photographs of all of Birmingham were gathered in digital format. This information was used to estimate the heights of certain buildings and other structures after attempts to obtain actual height data from mobile phone companies proved unsuccessful.

Meteorological data on wind speed, wind direction and temperature gradient from 1993 to 1997 in EXCEL spreadsheet format, courtesy of BESD Air Pollution Section.

A paper map of Birmingham in 1:25,000 scale marked up to show site boundaries, significant barriers and road parapets, elevated roads, roads in cuttings and the location of the 21 industrial sites included in the mapping exercise.

The Ordnance Survey Landline digital data, which was supplied in 500 metre by 500 metre tiles, was filtered and manipulated using the consultant's custom software to separate the different data elements, e.g. buildings and roads. By this process 1 kilometre by 1 kilometre tiles of each type of data were produced. These data were then saved as separate binary files using the original OS grid reference system of numbering with a prefix to denote the data type. Further files were then created using LIMA to represent bridges, elevated roads and road cuttings. These data were also saved as LIMA binary files. It is important to note that only 30% of the digital data on the 184,500 buildings in Birmingham was received in the form of closed polygons. Therefore, 70% had to be closed either using algorithms in the LIMA software or manually.

The centre lines of around 60% of all roads on the network to be mapped (880 kilometres) were obtained directly from Ordnance Survey Centre Alignment of Roads (OSCAR) digital data. The remainder had to be digitised manually from the geographical data supplied.

With the exception of elevated sections of road, such as the M6 motorway and flyovers, the base heights of roads were derived from ground height contours (Landform Panorama Data).

Elevated road sections were modelled using bridge elements. The height of these sections was estimated from the aerial photographs supplied.

The effects of parapets and screens of less than 0.5 metres above a road surface were ignored. Road cuttings were modelled by creating additional screens to simulate the effect of embankments and retaining walls.

Railway lines throughout Birmingham were manually digitised using the Ordnance Survey digital data supplied. In total 131 kilometres of railway line was included in the model.

The base height of all lines was assumed to be at ground level. No account was taken of the effects of elevated structures or cuttings.

5.4 NOISE IMMISSION DATA

5.4.1 Building distribution data

An A4 map showing the dispositions of the 1,360 individual 500 metre by 500 metre map tiles marked up with the approximate locations of all tower blocks.

5.5 NOISE MEASUREMENT DATA

In order to calibrate and validate the calculations carried out to produce the Sound Immission Countour Maps (SICMs) the noise consultants, with the assistance of BESD, undertook a series of noise measurements during the project. The duration of each measurement was one week and measurement was done at 4 metres height.

In addition to the above noise measurements, BESD supplied the noise consultant with long-term historical noise data from a number of sites in the City. The consultant also used these results for calibration and validation purposes.

In the case of Birmingham's first maps, the **spacing** of noise reception points is 10 metre, so a 10 per 10 metre grid was applied.

5.6 CALCULATION METHOD

The sound propagation model used in LIMA is based on the procedures outlined in part 2 of ISO 9613(8). This model has been used to calculate the long term sound immission levels in terms of LAeq(T) for the 10 metre by 10 metre reception point grid network across Birmingham from the A-weighted sound power levels of the various noise sources.

Initially the model was used to calculate the LAeq(T) levels under meteorological conditions favourable to the propagation of sound (so-called downwind conditions). The factors taken into account in the calculation procedures and modelled in the LIMA software are as follows:

- The directivity of the source.
- The attenuation due to geometrical divergences.
- The attenuation due to air absorption.
- The attenuation due to the ground effect.
- The attenuation due to obstacles including buildings, land contours, barriers, noise screens, retaining walls and cuttings.
- The attenuation due to miscellaneous effects (e.g. dense foliage).

No account was taken of reflections, although LIMA can calculate these effects.

However, to do so would have significantly increased the calculation times.

The calculations in LIMA were carried out from A-weighted sound power levels not from octave band sound power levels. Therefore, the alternative method for calculating the ground effect found in section 7.3.2 of ISO 9613 Part 2 (8), was employed.

In addition, the following assumptions were made for the air absorption effects:

- Rail and road traffic attenuation due to air absorption – 4dB per 1,000 metres.
- Industrial noise attenuation due to air absorption – 2dB per 1,000 metres.

No sound propagation calculations were necessary for aircraft noise as the data was provided by the Birmingham Airport as SICMs.

When the directivity and attenuation calculations had been carried out the resulting downwind (DW) Equivalent Continuous A-Weighted Sound Pressure Levels from the various sources were transformed into the long-term average values by applying the meteorological term CMET.

LAeq (long term) = LAeq (DW) – CMET

For further details on the propagation model and propagation calculations see the consultant's report (12) and ISO 9613-2(8).

5.7 INDICATORS AND MAPS

After carrying out all the calculations necessary to obtain the LAeq (long term) sound immission levels, the LIMA software produced results files for all of the separate 10 metre by 10 metre reception points across Birmingham. These result files consist of co-ordinate (X.Y), height and sound immission level data for day and night. To produce the SICMs of the different noise sources these results were converted to separate graphic files for day and night-time using one of the modules contained in LIMA. During the contour plotting process LIMA uses a routine to 'smooth' the contours obtained from the grid data.

SICMs showing the 'combined' noise levels of all the different sources, i.e. road, rail, aircraft and industry, were produced using a facility in LIMA which logarithmically sums the noise level data from the result files for these different sources. The maps showing

Birmingham in terms of the Noise Exposure Categories in PPG24 (5) were produced in a similar manner.

With the exception of the Noise Exposure Category Maps the noise maps were produced in the 5dBA bandwidths. The colours associated with each band have been taken from the recommendations in DIN18005 Part 2 (6) with the addition of a light green colour to depict areas of the City where the sound immission levels are less than or equal to 30dBA

5.8 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

Staff at BESD had no prior knowledge of noise mapping using modern computer based calculation and modelling techniques before the Birmingham Noise Mapping Project was started. Even though the authority employed a consultant with a proven track record of producing such maps, albeit on a smaller scale, the project still took approximately 10 months to complete. If such a consultant had not been employed it is unlikely that the project would have reached completion at the time of preparing this report. Indeed, with the current level of knowledge in the UK on modern noise mapping techniques there must be serious doubts that any local authority could successfully undertake such a project without the presence of high expertise.

Even though the ultimate responsibility for producing the maps rested with the consultant, the project team at BESD needed to have, and fortunately did have, an in-depth knowledge of acoustics, electronics and the use of modern computer technology for scientific purposes.

This knowledge was necessary in order for the project team to assist with, participate in and guide the mapping process. Local authorities that commission similar projects in the future will also need this level of 'in-house' expertise.

At the outset BESD found it impractical to produce a tender specification for the proposed project. However, as the level of knowledge on noise mapping improves in the UK, this may not be a problem for others who commission similar work in the future. Nevertheless, in many cases it may still be necessary to use the 'preferred contractor' approach employed by Birmingham. This normally requires local authorities to obtain exemptions from their financial standing orders.

In order for the project to be successful it was necessary at an early stage to draw upon the skills of officers working for other Council departments and to access data held by these departments. In short, an interdepartmental (corporate) approach to this project was essential from the outset.

In order for the project to be successful it was necessary to enlist the co-operation of outside organisations such as JDT, Railtrack plc and Birmingham International Airport plc.

None of these organisations were obliged to provide BESD with any information. Put simply, the production and supply of the raw data needed to calculate transportation noise, and possibly noise from other sources, is often outside the control of a local authority.

Several problems were encountered prior to and during the mapping exercise. As a result, critical decisions had to be taken by the project team.

6 DUBLIN CASE STUDY

6.1 INTRODUCTION

The objectives of the Noise Mapping Project in Dublin are among others to identify and quantify the scale of the noise problem in Dublin by providing information on the noise levels and hotspots to the City council and the public; assist in setting realistic targets for noise reduction and to provide a tool that permits the more effective use of planning controls.

6.2 EMISSION DATA

For the existing mapping purposes, noise from traffic has been assumed to be the dominant noise source. Therefore, train, aircraft and industrial point noise sources have not been included in the assessment as such. However, the municipality has made contact with the Airport and Rail Authorities for the official round of modelling for June 2007. The municipality has offered to run the rail model subject to receiving the required information from the rail authority and has also offered to incorporate the outputs from the airport model in the overall regional map for Dublin.

6.2.1 Road traffic data

Local authorities produce most of the data concerning traffic sources.

Several assumptions were made in relation to road data:

- % Heavy Goods Vehicles (HGV) composition remains the same throughout the day and night
- Road surface is the same composition throughout Dublin
- Vehicle speeds are as per 'built up area' limit of 30 mph
- City Council SCATS' (Sydney Coordinated Adaptive Traffic System) data and vehicular count data are representative of annual traffic flow data.
- Roads with no traffic flow data, assumed to be 50 vehicles/hr

6.2.1.1 Road sources

All major roads within the City Council boundaries were inputted into the prediction model. This resulted in 1305 road sources.

6.2.1.2 Traffic Flow

Traffic flow, that is the average number of vehicles passing along a link or road in one hour periods over 24 hours, had to be input into the model. Data on traffic is drawn from a number of sources. These sources are 1) manual traffic counts taken between 8 am and 6.30pm., 2) automatic traffic counts taken from the City Council's SCATS system and 3) derived traffic counts which were based on one hour manual counts and extrapolated using a traffic flow diurnal variation chart which was develop in house using over 700 roads\ links on the SCATS system. Where there is no data available on traffic flows a default value of 50 vehicles per hour is entered, as the model is not designed for flows less than this.

6.2.1.3 Traffic Composition

A break down in traffic composition was required between HGV and others, i.e. cars. This was achieved in two ways. The average hourly percentage of HGVs contained in the manual traffic counts for years 2001 and 2002 and between the hours of 8am and 6.30

pm was calculated and applied to those roads where the manual count was available. The second way was to again calculate the average hourly traffic counts from the manual counts and assigned the average value to classes of roads as defined in the 'Directions for the Control and Management of Road Works in Dublin'. This was completed for all of the data obtained from the City Council's SCATS data. (Sydney Coordinated Adaptive Traffic System)

6.2.1.4 Carriageway Width

As there is no database available on the width of roads in the city, the mid point of the road or link was used through which the width of the roads was measured. Again, it is not considered that this will lead to major inaccuracies in the model.

6.2.1.5 Model to calculate noise from roads

The method used for calculating current noise levels was the 'Calculation of Road Traffic Noise' (CRTN) from the Department of Transport and The Welsh Office - 1988 version. It is recognised as a method for predicting noise from road traffic and it is also appropriate for more general applications such as environmental appraisal of road schemes and land use planning. This version revises the original published in 1975 and extends the method to cover a wider range of applications covering both free and non-free flowing traffic.

6.3 NOISE PROPAGATION DATA

It was assumed that Dublin is flat, and therefore no map of height-contours is needed.

Regional maps are taken from the Ordinance Survey, and land use are purchased from private companies.

The CRTN model does not require meteorological data to be entered so therefore it was not used. For built up areas it was not considered critical to use meteorological data either.

6.4 NOISE IMMISSION DATA

6.4.1 Buildings

Individual building heights for each building, purchased from a private company, were entered in the model. These heights were derived by multiplying the number of floors in a building by a floor to ceiling height of 8 foot and an addition of 7ft of attic space. While not exact, it is considered that this will not lead to major inaccuracies in the model.

All the buildings were individually inputted into the prediction software.

6.4.2 Population

Population spread from the national census is purchased from private companies.

6.4.3 Receptor Height

The receptor heights were placed at four metres as advised by the Working Group on the END. This helps avoid, to some degree, the necessity of entering low garden walls, street furniture etc. into the model.

6.5 CALCULATION METHOD

The strategic noise maps are computed using a proprietary noise model, called 'Predictor'. This model produced calculations of the L1018Hr sound levels at 3,985,821 receiver points throughout an area, with receptor points placed at every 10 metres. The input of information on the receptor points and on 344,183 buildings leads to a total continuous computation time of 3,504 hours or 146 days.

The predicted values of the 3,985,821 reception points were then inputted into a mapping software which extrapolated the receptor points to 7,971,642 and outputted these in the form of graphics and colour contours. The total area covered by the noise mapping project was 146Km2.

The Predictor model output is based on the Calculation of Road Traffic Noise (CRTN), a standard that is commonly used both here in Ireland and Great Britain when assessing noise from traffic.

A desktop GIS system (MapInfo) integrates the noise model outputs, population densities, land use data and traffic flows into a database, which is easy to interrogate. All the calculations and statistical analysis are carried out with the GIS software.

6.6 INDICATORS

The Transport Research Laboratory (TRL) in Great Britain has developed conversion factors for the L10 18hr indicator so that it may be expressed as an Lden or Lnight. Whilst the L10 18hr can be converted to these new parameters, as no standard or limit has been selected as to what levels are appropriate, the contour maps have been produced in the L10 format.

6.7 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

Noise responsibles from Dublin municipality consider that END is ambiguous in many parts. They also mention that noise mapping needs a long lead in time and that the gathering of data is time consuming and expensive.

The main problem encountered was the lack of data, including land use data, building height data, detailed population data per household and other detailed data that has to go into the software models such as traffic speeds, lane widths, railway speeds, ground elevation information, ground cover information, among others.

Some general assumptions had to be made in relation to the model. This was mainly due to lack of information. However, experts do not considered that these assumptions cause a significant error in the model. This conclusion is supported by the validation procedure.

7 GREATER LYON CASE STUDY

7.1 INTRODUCTION

Greater Lyon is the organisation responsible for urban planning in the Lyon region. Greater Lyon has undertaken a LIFE Environment project called « GIpSyNOISE » to develop a GIS based tool for decision-makers that can be used for estimating noise levels and determining the size of the exposed population. The project is funded by the French Ministry of Ecology and Sustainable Development and by the European Union.

GIpSyNOISE will be used to pinpoint areas with unacceptable noise levels and assist decision-makers in implementing urban development plans for reducing them. It will also propose means of communication toward the public through noise maps as requested by the European directive on assessment and management of environmental noise.

7.2 NOISE EMISSION DATA

7.2.1 Road traffic Data

The municipality of Lyon and the Mobility Office of Grater Lyon provides vehicle count data: number of vehicle per hour, speed, traffic flow and the percentage of heavy goods vehicles.

Some uncertainties concern vehicle traffic data, as some road counts were made in 1999 and others in 2003. Other uncertainties relate to the number of vehicles; for some roads there was a day average (24h), and it needed to be divided into day, evening and night periods. Some data was not digitised and was available only on paper.

7.2.2 Railway Data

In France rail management is undertaken by two organisations: RFF (Réseau Ferré de France) and SNCF (Société Nationale Chemin de fer Français). RFF will provide geographic information on rail sections, rail structure, disconnection and height, SNCF will provide information on rail traffic: number and type of trains and percentage of breaking vehicles, among others. The quality of these data is not yet known.

7.2.3 Industry Data

Information on industrial noise sources is obtained from various sources. The Chambre de commerce et de l'industrie (Industrial and Commercial Chamber) is responsible for the relations with industries. The Direction Régionale de l'Industrie, de la Recherche et de l'Environnement (Regional Office for Industry, Research and Environment) is in charge of industrial policy. This administration will provide information on maximum allowed noise levels each industry. Surface noise had to be considered. Problems were encountered when trying to identify maximum noise levels for all industries. In some cases the maximum levels are established only as emergency levels. For instance, industries are allowed to emit 3dB more than the ambient noise.

7.2.4 Aircraft Data

Information from airports is gained from the Industrial and Commercial Chamber, particularly the department responsible for the management of both airports, which will provide grid data on noise exposure. In France aircraft noise exposure is expressed in "Psophic Index". This index had to be transformed into Lden by a mathematical operation.

7.3 NOISE PROPAGATION DATA

7.3.1 Topography data

Topography data has been obtained from Grand Lyon's GIS federal data in the format of contour lines or height points. The layer quality is quite reliable.

Road traffic geographical data such as road surface, slope and relative height in two dimension position of the road section is partially obtained from the Road Department of Grand Lyon and partially available in Grand Lyon's GIS database.

7.3.2 Ground absorption

Ground Absorption is extracted from the GIS layer of green spaces, urban parks, and farms. This information is available in Grand Lyon federal data. Geographical treatment of the data had to be done, which involved merging the various surfaces and reject surfaces under 1km² of ploughed ground, where noise reduction is unperceivable.

 The GIS layer on building heights is available within the Grand Lyon federal data, and the quality is good. For some cities, buildings' height is not available. This parameter is essential for noise calculation. The type of building is also needed to identify sensitive zones around schools, hospitals, etc.

7.3.3 Noise barriers

The Noise barriers' layer is partially available in Greater Lyon federal data. Data on height of the barriers and reflection loss is subsequently introduced one by one. The quality of the data is good.

7.3.4 Reference Map

The reference map used is a land use map, where commercial, industrial, residential, or sensitive areas around some buildings (hospitals, schools, etc.) are shown.

It would be used to lay down objectives, or limit values for each area. We made this layer from our local plan of town planning.

7.4 NOISE IMMISSION DATA

7.4.1 Population

Information on the number of inhabitants per residential building is available in Greater Lyon federal data. The uniformity of the data will decrease over the next years, because the updating of the database will be done separately by each of the municipalities of the Grand Lyon region.

7.5 CALCULATION METHOD

GIpSyNOISE (see annex 7.5) is the integration of noise propagation calculations within a GIS: ArcView8.3©, distributed by the company ESRI, used with the extension Spatial Analyst provides visualisation of maps and Cadna-A©, distributed by the company Datakustic, estimates noise levels in each cell of the grid.

The use of these two software packages is transparent to the end-user: The end user interacts with the GIS system using a menu system, whereas Cadna-A© is fully integrated within ArcView. A specific development provides the others functions and userfriendlyness aspects for non-acoustic or non-GIS experts. It implies the characterization of current state, decision-making aid through the comparison of scenarios, the definition of action plans, and the communication near the public.

7.6 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

This information could not be provided because noise experts at Grand Lyon could not be again contacted due to the timing of the report.

8 LONDON CASE STUDY

8.1 INTRODUCTION

The information for this case study was obtained from the report "The London Road Traffic Noise Map" of the Noise Mapping England project (see references).

The London Road Traffic Noise Map is one element of the Government's national ambient noise strategy. It provides information on the levels of road traffic noise across the whole of the Greater London Authority's area. Other types of noise will be covered by projects that are being planned or progressed at present. The general working scheme for noise-mapping in London is presented in annex 8.1.

The London Noise Map is the first detailed noise map of the whole of London and will necessarily be limited by the availability of some types of information. But at the same time, it is forming a focus for gathering together the huge body of information already available into a coherent set of data.

The UK Department for Environment, Food and Rural Affairs (DEFRA) contracted WS Atkins in January 2003 for the completion of the London Road Traffic Noise Map on March 2004.

8.2 NOISE EMISSION DATA

This mapping exercise does not include traffic using local access roads, nor any other sources of noise, such as trains, aircraft or industry.

8.2.1 Road Traffic Data

The London Atmospheric Emissions Inventory (LAEI) gave a first approximation of the roads to include, the location of the roads and details of traffic flows.

This information is being processed to give the required geographical accuracy, and the traffic flows themselves have been converted into the form needed for noise calculations. The position of the centre-line of the road and the width of each road segment is required. A program calculates the road width from the Ordnance Survey MasterMap.

The project has considered over 5,200 kilometres of road drawn from the LAEI database. These roads were represented by some 120,578 road segments with more than 21,100 different traffic flows distributed over the network. The network represents the busier roads, not every road. There are some segments with very low flows, and the maximum is 171,800 vehicles in the 18 day (6am to midnight).

Average speeds used in the calculation range from 20km per hour to 106km per hour. There were over 2,300 noise barriers (including walls large enough to function as barriers but excluding buildings and ground topography) covering a total length of about 120km. Any roads with speeds below 20 km/h were assigned speeds of 20km/h to bring them into the range of validity of the Calculation of Road Traffic Noise (CRTN).

A further requirement of the project was to provide information on noise levels generated by all modelled roads and separately for major roads. The END requires the mapping to include this classification of road type, and includes a flow threshold of 6 million vehicles per year (for the first round of mapping and equating to 16,438 vehicles per 24-hour day).

Major roads were defined as roads within the Transport for London Road Network (TLRN) and motorways.

The table below presents the names of the datasets and used to obtain the parameters required for the noise propagation model.

Input Parameters Required	Existing Data Set Used
Road Widths	OS MasterMap®
Road centre lines	OSCAR Asset Manager®
Road traffic flows (linked to OSCAR by GIS processing)	London Atmospheric Emissions Inventory
Traffic flow conversion factors (by year and by time of day)	National Traffic Statistics
Road type (major / other)	TLRN (from TfL)
Carriageway type (one way / two way)	Observation
	New data source[5]
Road surface type Location of purpose built noise barriers	Borough data request

Figure 3 - Data sets and sources of the road parameters

8.2.1.1 Road categories

Roads have been categorized as follows according to their Average Annual Daily Traffic (AADT) flow so that the contribution of noise from different parts of the road network can be shown:

- Major roads in LAEI with AADT flow >16,438;

- Major roads in LAEI with AADT flow >8,219, <16,438;

- Major roads in LAEI with AADT flow <8,219;

- Other roads in LAEI with AADT flow >16,438;

- Other roads in LAEI with AADT flow >8,219, <16,438;

- Other roads in LAEI with AADT flow <8,219.

8.2.1.2 Road surface

Initial enquiries showed that the main highway authorities did not yet have suitable information on road surface types or on purpose-built noise barriers. Consequently, this information was sought from the London Boroughs. It was also important to gather local information about non-standard road surfaces and roads that deviated from ground level.

Road surface types requested included:

- Brushed concrete;

- Textured concrete;

- Whisper concrete;

- Surface dressed concrete;

- Hot Rolled Asphalt with surface dressing;

- Porous asphalt;

- Thin wearing course;

- Stone Mastic Asphalt.

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[5] These data were not available from any existing data source and were therefore requested or commissioned for the study.

A noise correction factor was then assigned to each road surface type for use in the model.

8.3 NOISE PROPAGATION DATA

8.3.1 Meteorological data

Regarding the meteorological conditions, it is assumed that roads are dry but the wind is adverse (blowing from the road to the receiving position).

8.3.2 Ground Contour

The Ordnance Survey Profile ground level contour data forms the baseline for the creation of the 3D world inside the NoiseMap software. However it does not supply all the height information required.

For the extra level of detail, road and embankment height data are obtained from aerial photography.

The topographical model (defining the ground contours and type of ground cover) included over 138,000 polylines, with 1.1 million vertices (data points). Ground heights ranged from 4m below mean sea level to 267m above mean sea level. Local topography was built into the model by creating a 3D representation of the TRLN, using photogrammetry techniques. This was also done to capture in 3D the man-made cuttings and slope features that form part of and surround the TLRN and to capture the location and heights of acoustic barriers affecting the TLRN. It was also agreed that railway embankments acted as significant noise barriers in many places, so it was opportune to create a 3D representation of the rail network in London.

It was decided that noise calculations would be made on the presumption that groundcover is "soft" (i.e. absorbs sound) unless otherwise defined.

8.3.3 Noise barriers

Noise screening, including boundary walls, which are large enough to provide protection, as well as purpose-designed noise barriers, is an important source of noise attenuation across London. However, information regarding these features is elusive. Local authorities and the Highways Agency hold no consistent data, and due to the very thin nature of noise barriers, their heights are erratically picked up (if at all) when using modern Digital Terrain Model techniques such as laser scanning. CRTN places great importance on path difference when calculating noise levels, so a missing barrier will have a large effect on many houses. Therefore, photogrammetry was used to obtain the location and heights of any barriers along the road network.

Apart from purpose-built acoustical screening and the impact of terrain and landform, the main barriers to noise attenuation in the urban environment are the buildings themselves. Each and every building that potentially has a screening effect must be included in the noise calculations as a "barrier" object. Each building is processed during the calculation step. For this prototype noise map of London all buildings will be modelled with an assumed height of 8m above local ground, although considerable effort has been taken to ensure that actual building heights can be added later. It is a requirement that the model can be updated to reflect any adjustments to the building heights. This was based on the experience in Birmingham, which suggested that for strategic maps of this kind, this would provide acceptable accuracy.

The following table contains the data sets and the sources of information where the data was obtained.

Input Parameters Required	Existing Data Set Used
Side slope location and widths Areas of acoustically hard ground (water bodies, etc.) Printed maps for manual surveys	OS MasterMap®
Natural ground topography	Land-Form PROFILE®
	New data source[6]
Man-made topography (side slopes, road heights) Retained cuttings Elevated roads, bridges Railway topography	Photogrammetric Interpretation of orthorectified stereo imagery (For roads, only on TLRN)
Location of purpose built noise barriers	Borough data request

Figure 4 - Data sets and sources of the noise propagation parameters

8.4 NOISE IMMISSION DATA

Building types were defined as dwellings, schools or hospitals.

Areas of interest were identified from the mapping and by consultation with officers at Southwark Council. These areas were surveyed on foot and the data was added into the NoiseMap model back in the office.

The population information was drawn from the Census 2001.

Input Parameters Required	Existing Data Set Used
Population density	Census Output Areas
Building type Number of households	ADDRESS-POINT®
Building outlines	OS MasterMap®

Figure 5 - Data sets and sources of the noise immission parameters

8.5 CALCULATION METHOD

The software being used for this project is WS Atkins Noise Map 2000 SE. One of its strengths is its ability to work with GIS data. Information can be fed directly into NoiseMap 2000, where it is automatically converted into the objects used by the CRTN methodology. It allows a large number of computers to collaborate on the calculation process. The database is visible from the Internet and, later in the project, with suitable software it will be possible for stakeholders to see and to use this noise model.

In the CRTN method of noise prediction, the principal features that need to be represented are as follows:
The noise source:
- Vehicle flow rate;
- Percentage of heavy vehicles (defined as vehicles with unladen weight > 1525kg);
- Mean vehicle speed;
- Gradient of road;
- Road surface characteristics;

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[6] These data were not available from any existing data source and were therefore requested or commissioned for the study.

The noise propagation path:
- Perpendicular distance of receptor from source;
- Average height of propagation above ground surface;
- The acoustic characteristics of the ground surface;
- Angle of view of source from receptor;
- Path difference over barriers that interrupt the line of sight;
- Reflecting surfaces close to the source.

8.6 INDICATOR AND MAPS

The calculations were to be made in accordance with the methodology prescribed in Calculation of Road Traffic Noise (CRTN)[7], which calculates noise levels either in terms of the LA10 (18 hour) index or the LA10 (1 hour) index. For this project, these results were to be modified in accordance with a procedure devised by the Transport Research Laboratory (TRL)[8] to derive the noise indices Lday, Levening, Lnight and Lden as defined by the Environmental Noise Directive. The calculations were to be made on a square grid covering the whole of the calculation area at 10 metre grid intervals and at a height of 4m above ground level.

As indicated earlier, results for a range of noise indicators were calculated, differentiating between so-called major roads and all modelled roads (see above). Consequently, each grid point has 25 noise level results associated with it.

Maps of London can be found in annex 8.6.

8.7 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

The experience from the Birmingham Noise Map showed that one of the greatest challenges for the London map would be acquiring the relevant data. Whilst in setting up the London project much preparatory work was undertaken to identify and acquire the necessary databases, a lot of time was still spent capturing data to fill the information gaps. The main focus of data acquisition centred on the ground profile along the road corridors – identifying when the road was elevated or in a cutting, and the size and extent of embankments. These features materially affect the propagation of sound from the roads and hence the noise impact.

With the help of the London Boroughs, reasonably good information was obtained about road surface type. This factor is important because, strategically, adopting a policy of using quieter road surfaces wherever possible is an example of an action that could be taken to reduce the noise from road traffic. However, if the map did not properly reflect the current road surface type, it would not be possible to test the effect of such a policy through the mapping process.

The other main point on data was the time needed to modify existing data to ensure it was fit for its required purpose and then to integrate all the datasets together in the noise calculation software to build the complete 3-dimensional digital model of London. This included assigning the road flow information to the correct sections of road with sufficient geographical accuracy, and draping the completed road network over the ground model. Buildings were also placed on top of the ground model. It is clear that, for future mapping, investigations should be carried out to see if that part of the process could be made more efficient.

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[7] DOE / Welsh Office Memorandum Calculation of Road Traffic Noise, 1988

[8] Abbott PG, Nelson PM, Converting The UK Traffic Noise Index $LA10,18h$ To EU Noise Indices For Noise Mapping, TRL, 2002. The report can be seen on the Defra website: http://www.defra.gov.uk/environment/noise/research.htm

An important factor with these results is to remember the basis upon which they have been derived. Because the current national road traffic noise prediction method provides results in terms of the LA10 parameter, the results for the various indicators of interest (Lden, Lnight etc) have come from an empirical formula derived from a statistical analysis of road traffic noise measurements. This means that the Lnight values presented are only an estimate of the night noise impact based on the daytime flows contained within the LAEI and the empirical relationship that has been previously derived.

One feature that has been observed from the results concerns the interpretation of the road type required by that empirical formula. The statistical analysis carried out y TRL produced a different formula for non-motorway roads compared with motorways. This was rigorously applied in the London Road Traffic Noise Map. However, close examination of the area where the North Circular Road meets the M1 showed an anomaly. This has been attributed to the fact that the North Circular Road, for the purposes of this empirical formula, behaves more like a motorway, even though it is not formally classified as such. Thus there may be a case in future for classifying roads not strictly by their Motorway / non-Motorway classification, but by considering whether or not, acoustically, they are like a motorway.

Finally, great care must be taken when examining the results for a specific location. Whilst huge efforts were made to represent London properly within the map, cost-benefit issues had to be considered when deciding the extent to which precise information was secured for each location. This is a strategic map, and as has been seen from the results, a strategic indication of the scale of the road traffic noise impact has been obtained, together with an indication of where that impact is occurring. This does provide a platform upon which noise control policies can be reviewed.

Since the commencement of the London Road Traffic Noise Map project, the capture and quality control of geographic data has improved. There will, therefore, be scope to improve the quality of future strategic maps in a cost effective manner. Clearly, these opportunities need to be reviewed and where appropriate taken in the future mapping work.

9 STOCKHOLM

9.1 INTRODUCTION

The City of Stockholm has been surveying noise since the early 1970s. In the beginning the work was concentrated on noise maps from road and rail traffic. During the years the field has been broadened. During the last years the municipality has started up a mapping over the whole Stockholm area in a computer- and GIS-based way, following the END.

9.2 EMISSION DATA

9.2.1 Road data

Digital maps of roads (Arcview format) were available but the related information on traffic flow, speed and percentage of heavy good vehicles was in paper format and had to be digitised.

The Transport Department at the municipality of Stockholm provided road traffic flow data in the format of Average Annual Daily Traffic Intensity (AADT) for the main roads. The values were calculated on-ground by the Swedish Road Administration between 2000 and 2001. The values were obtained for weekdays but were later extrapolated to weekend days.

In order to calculate the Lden indicator it was assumed that 72% of the road traffic corresponded to the day period, 20% to the evening and 8% to the night period.

Both the average speed and the percentage of heavy good vehicles were obtained from a traffic survey from the Transport Department carried out in 1994.

9.2.2 Railway data

The Swedish National Railway Administration provided data on the types of train, speeds, and lane widths in different track areas. Again, the railway network was available in GIS format but the additional information had to be digitised.

The railway speed was deduced from the limit speed of the railway vehicle and of the track area.

The underground information was obtained from the municipality of Stockholm.

9.2.3 Aircraft data

The airport Authority in Sweden produced its own noise map according to the specifications from the consultant company who made the calculations of the noise map in Stockholm. Noise values are divided between day and evening, as there are no flights during the night. This information was incorporated into the general map production system.

9.2.4 Industry data

No specific source data for industry is available. As an approximation the Environmental Department of the city of Stockholm provided the location and the borders of specific industrial facilities. It is assumed that industries respected the legal noise limits, therefore these values, divided by day, evening and night, are assigned as emission values to the contours of the industrial facilities.

9.3 PROPAGATION DATA

Digital maps of the terrain are provided by the local Environmental Department, including obstacles and barriers.

The only meteorological data that the model allows as input is a constant wind speed of 3 metres per second and always from the noise source to the reception point.

9.4 IMMISSION DATA

9.4.1 Buildings

There is information on the base are of buildings but not on building height. The following assumption is mad:

- All buildings with a base area smaller than 20 square metres have 3 m height.
- All buildings with a base larger than 20 square metres have a height of 7 metres.
- Certain higher buildings are assigned with a mean value of 20 m.

9.4.2 Population

The municipality of Stockholm has statistics on population distribution by building area (it can include about 150 building units), but not by specific building. The fact that inhabitants of Stockholm are not registered by building makes it difficult to connect building and population data.

9.5 CALCULATION METHODS

The following table summarises the calculation models used in the city of Stockholm.

Noise source	Calculation model
Roads	1996 version - Nordic Calculation Model – Report number 46953
Railway	1998 version - Nordic Calculation Model - Report number 4935
Industry	General Prediction Method for industry
Aircraft	Nordic calculation Model – SVERIM

Figure 6 – Calculation method used for each of the noise sources

9.6 MAPS AND INDICATORS

Noise maps of 2x2 m grid and 4x4 m grid were produced. The results are presented by each individual source as well as by all sources together and the indicators shown are Leq(24h) and Lden (see annex 9.6).

Maps are put into a computer system together with information about noise reduction measures as insulation of the windows (to reduce the noise levels indoors) and noise barriers. The result is a computer system with a collection of all available data about noise: Both noise levels, the number of windows and noise reducing measures, results and so on.

9.7 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

The noise expert at the consultant company highlights two main data problems: the lack of building height data and the lack of population data assigned to single buildings. Another comment mentioned is that more digitised data would be desirable because, in fact, the main part of work is not devoted to the calculations but to the preparation of all the input data.

10 VIENNA CASE STUDY

10.1 INTRODUCTION

The municipality of Vienna, with about 1.6 million inhabitants, is a federal state at the same time.

In Austria the legislative powers in respect to noise lie in the authority of the federal government as well as in the authority of the nine federal state governments. The city of Vienna is one of them. The enforcement of the directive 2002/49/EC relating to the assessment and management of environmental noise in Austria therefore made necessary some technical work to ensure a uniform enforcement by the different legal authorities - while the implementation of the directive is accomplished by ten legislative acts of the federal government and the nine federal state governments, technical guidelines had to be developed to ensure a consistent outcome.

The following sources are falling into the authority of the federal government: railways; motorways; airports / air traffic; partly the sites for industrial activities subject to the directive. The other sources are falling into the authority of the federal state governments. The other sources are: roads (motorways excluded); the remaining sites for industrial activities subject to the directive.

The legislative act for the implementation of the directive 2002/49/EC by the federal government came into force on 4th of July 2005 (Bundes-Umgebungslärmschutzgesetz – Bundes-LärmG). It regulates the competent authorities at federal level as well as the scope. Exceeding the directive it is stated in this law that in the noise maps for the year 2012 all motorways and airports – independently of their annual traffic volume – will be covered by noise maps.

Agglomerations are defined as areas with a population density above 1000 inhabitants per sqare-km (based on the extent of communities or part of communities). As the population density in some communities adjoining the city of Vienna meet these demands the agglomeration of the city of Vienna will include also parts of the federal state of Lower Austria (the communities Perchtoldsdorf, Brunn am Gebirge, Maria Enzersdorf, Mödling and Wiener Neudorf). Technical specifications like the time periods for the different noise indicators and the computation methods will be fixed with an ordinance to the Bundes-LärmG.

The legislative act of the federal state of Vienna has been under survey in May/June 2005 and is expected to come into force soon. It covers only road noise (except motorways) and sites for industrial activities subject to the directive 2002/49/EC.

According to the proposal it is planned to fix the periods for the different noise indicators with

- 6.00 – 19.00 o'clock for the L_{day},
- 19.00 – 22.00 o'clock for the $L_{evening}$ and
- 22.00 – 6.00 o'clock for the L_{night}.

In the proposal all areas with a maximum L_{den} of 50 dB and L_{night} of 40 dB (for the sum of all noise sources except air traffic) exceeding the size of 10,000 m^2 are defined as "quiet area in an agglomeration".

The values for L_{den} and L_{night} have to be obtained exclusively by calculation.

The implementation of the END directive has implied several changes both in the way noise indicators were being calculated in Austria and in the adaptation of the existing guidelines for the Austrian noise computation methods.

New technical guidelines tackling most of the aspects of the END had also to be developed to ensure a uniform implementation of the directive in Austria (e.g. provisions for the calculation models to be used or the modelling of the different noise sources types).

A great deal of the work for the technical guidelines (the main guideline is No. 36-2) was done by the Forum Schall, an association of members of the authorities of the nine countries of Austria and their main capitals, and the Austrian Noise Abatement Association (ÖAL) – a non-governmental organisation.

10.2 NOISE EMISSION DATA

10.2.1 Road traffic data

The traffic volume for the main roads or road segments is available separately for passenger cars and heavy good vehicles. The division between day, evening and night periods is not available and standard values given in the calculation method have to be used.

At the local government department "MA18 – Urban development and planning" a traffic model for the whole city is run. Traffic volume data are obtained from both automatic and manual counting in combination with a traffic assignment program (VISUM).

The value for Daily traffic volume (dtv) is not available for all roads and it is necessary to assign dtv-values for the lower level road network. Therefore it is planned to define six classes with dtv-values and roads with unknown dtv-values will be categorised together with the local government department "MA46 – Traffic organisation and technical traffic issues". For all roads the location is given via the so-called RBW-code (RBW is the abbreviation for "Räumliches Bezugssystem Wien", which is a spatial frame of reference for the city of Vienna).

Further information needed for the calculation of the noise emission level like the size classes for the heavy good vehicles are not known and standard values given by the calculation model RVS 3.02 will have to be taken instead. The standard values in the RVS 3.02 are given for four different road types (current version of the adaptation of the RVS 3.02 with regard to the directive 2002/49/EC, not yet published).

The road network in Vienna has a total length of about 2800 km. For approximately 1000 km the dtv-values are known, the remaining road network consists of smaller roads (see above). About 51 km of the road network are motorways and fall into the authority of the federal state government. About 287 km (motorways not included) have a traffic volume higher than 6 million vehicles per year and 191 km show a traffic volume between 3 and 6 million vehicles per year.

10.2.2 Railway traffic

Railway noise in the city of Vienna is emanating from the Austrian federal railway as well as from the tram and underground systems.

Tram and underground lines are recorded separately at line level. Information on the spatial position and the traffic volume for the different time periods (day, evening, night) as well as emission data for the wagons is available at the tram and underground line operator "Wiener Linien". The total length of the tram system in the city of Vienna is 184 km (directions are not counted separately) and the length of the underground system is 64 km.

A digital model is not yet available at the federal railway operator for the federal railway system.

10.2.3 Sites for industrial activities

Depending on the type of industrial sites subject to the directive, some plants sites fall under the authority of the community administration and some others under the authority of the federal government. There is no corresponding plant in the city of Vienna falling into the community's authority; data on plants under the authority of the federal government are not yet available.

10.3 NOISE PROPAGATION DATA

10.3.1 Surface Information

There is information on the degree of absorption (e.g. green areas) and reflection (e.g. water surfaces) for areas of at least 1 square metre. Areas with a minimum size of 10 m^2 will be taken into account once the noise maps are calculated. For facades reflection a coefficient of 0.8 will be used.

10.3.2 Digital Model

For the calculation of the noise maps a digital terrain model is necessary. A terrain model including building data is available at the community administration department "MA41 – Urban surveying". Basis for the data have been orthophotos as well as terrestrial surveying.

10.4 NOISE IMMISSION DATA

10.4.1 Building Data

The data contain building outlines as well as the height of the eaves. While the accuracy of the building outlines is in the range of 0.01 m the inaccuracy for the height data in areas with a high habitat density is smaller than 0.1 m. In less dense areas the inaccuracy for the height data is smaller than 0.5 m.

As it is assumed that too detailed cladding information (ledges, oriels) will increase the calculation time without benefit for the result, a smoothing on a 0.25 m level will be performed to reduce the amount of information.

10.4.2 Height Model

For the total area of the city of Vienna contour lines are at hand at 1 m intervals (height). Additionally, in the digital model edge and upright shapelines are available where discontinuities are high. The information for this additional data predominantly comes from terrestrial surveys.

"Flying" through the model allows the validation of the plausibility of the 3-dimensional geo- and building information imported in the calculation program visually.

10.4.3 Population Data

The population of the city of Vienna is available at the community administration department "MA62 – Elections and various legislation issues" as number of persons per counting unit. The counting unit is set up at building level, whereas a breakdown after staircases is made. The data have their origin in the registration evidence and can be spatially assigned by an address code.

10.4.4 Calculation

Due to the fact that the harmonised calculation model "HARMONOISE" is not ready for use by now, national calculation models are laid down in guideline No. 36-2 to be used as interim methods.

Noise source	Prediction models
Road traffic	Technical rule RVS 3.02 – "Environment Protection – Noise Protection"
Railway	Technical rule of the Austrian Standards Institute and the Austrian Noise Abatement Association ON-Regel 305011 – "Determination of noise immission caused by rail traffic – Railway traffic, shunting and cargo handling operations"
Aircraft	ÖAL-guideline Nr. 24-1 -"Noise protection zones in the vicinity of airports – bases of calculation and planning"
Industry	ÖAL-guideline Nr. 28 and ÖAL-guideline Nr. 28, amendment 2 – "Sound emission and propagation"

Figure 7 – Prediction models used to calculate the noise emission

The prediction models for railway noise and road traffic noise are based on the calculation methods of the general prediction model described in ÖAL-guideline Nr. 28.

For the calculation at local level the computer programme Cadna-A© from Datakustik GmbH will be used. First test runs are currently carried out. The size of the separately calculated tiles will be 2.5 times 2.5 km. If needed – e. g. in areas with a high population density – smaller tiles will be used. The format of the output will follow the ÖAL guideline No. 36-2 – the noise level zones will be indicated by fixed colours in 5 dB – intervals (isophones saved in a dxf file format). The number of affected people will supposedly only be given as one value per noise zone for the whole city of Vienna.

10.5 INDICATORS AND MAPS

Maps of Vienna can be found in annex 10.5.

10.6 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

Due to the separate competences for noise legislation in Austria a complex implementation of the directive 2002/49/EC was necessary. As responsibilities have not been changed with the implementation of the directive, noise maps have to be produced by different competent authorities. Especially for road traffic noise a high level of overlapping is to be expected. By now it is not yet clarified if the calculation of the noise maps will come to lie in only one authority – at least functionally.

11 VITORIA-GASTEIZ CASE STUDY

11.1 INTRODUCTION

The Department of Environment of the Vitoria-Gasteiz municipality had the initiative to start the noise mapping activities. It coordinates a working group that comprises the Department itself, the Centre for Environmental Studies (CES), which is an environmental engineering of the municipality, and the Centre for Applied Acoustics, which is a private company that runs de models.

Parallel to that, the Department of Environment holds three or four times a year meetings of the Noise mapping follow-up group. This group includes the main stakeholders involved in the noise mapping process and the main objective is to exchange both input data and at the same time share the noise impact results of the activities that stakeholders are producing. Of special importance is the involvement of other municipality departments (e.g. urbanism, transport), which are directly involved in the management of the noise sources.

For the municipality of Vitoria-Gasteiz it was very important that the mapping exercise was not a simple collection of data but that it became a management tool to be applied for noise prevention and planning and that could be used for those departments that had to meet decisions that affected noise quality.

Another important aspect is that the responsibles opted for an integrated assessment of the noise problematic, together with other environmental topics and other information coming for various municipality departments. Therefore, the noise data gathered during the mapping process and the results of the mapping exercise are integrated into a wider Environmental Information System (EIS) of the Municipality of Vitoria-Gasteiz.

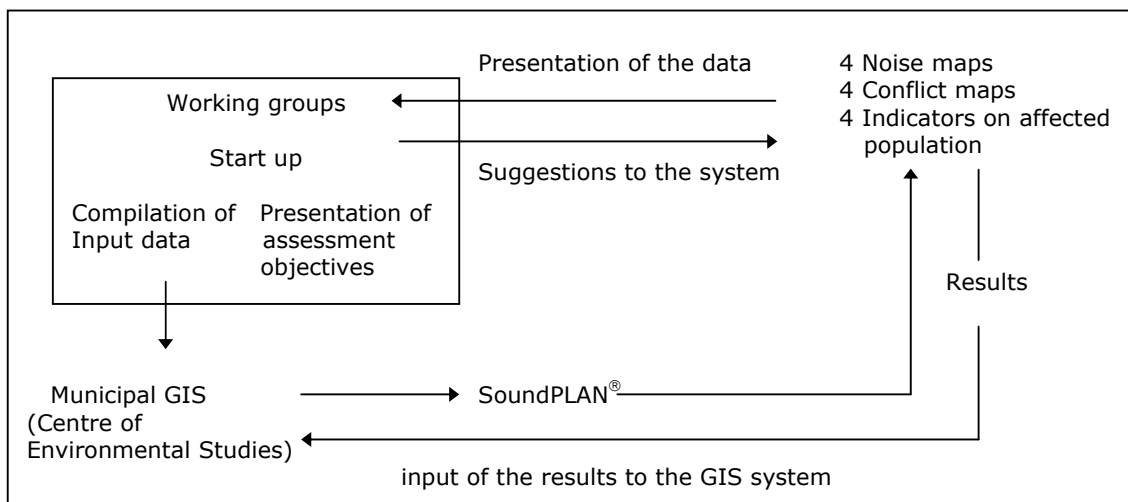The following scheme summarises the noise mapping procedure.

Figure 8 – Noise mapping work scheme

11.2 NOISE EMISSION DATA

The noise sources considered in Vitoria-Gasteiz were: streets, roads, railway and industry. Airport noise assessment is currently being updated separately, as the airport is in the outskirts of the city and it has been considered more appropriate to have its own assessment.

11.2.1 Road data

The Unit of Mobility and Transport of the Urbanism Department had available daily traffic capacity for most part of the urban area. The more than one hundred traffic-count stations are located in crossroads regulated by traffic lights with counts every 15 minutes. As suggested by the traffic technicians, the daily average traffic intensity was estimated as an average of the capacity from a week in May and a week in July, as representative of the mobility patterns in two different seasons of the year.

For the rest of streets that did not have traffic count stations, the values were given according to proximity factors or, with the collaboration of the Unit of Mobility and Transport, assigning traffic intensity levels to stretches that had similar characteristics than those with traffic count stations.

Other specific attributes for each of the stretches are: percentage of heavy good vehicles, speed, type of road surface and traffic regime, among others.

A GIS layer was created containing the roads within the municipality from the information provided by the Department of Public Works and Transport of the Provincial Council of Álava. From the data provided by the Department, each road stretch was assigned with data on Average Daily Intensity, percentage of heavy good vehicles and a mean speed for each road type.

11.2.2 Railway data

A similar GIS layer was produced for railway traffic from the information obtained from RENFE (Spanish National Railway Network). However, RENFE is no longer allowed to provide information, as they are planning to produce noise maps themselves. Information of train frequency can be obtained in the website and the speed is already known by the municipality because the municipality established limited speeds for trains passing through the city.

11.2.3 Aircraft data

As mentioned above, aircraft data is computed separately as the airport is located at the outskirts of the city. Currently there is an update of the previous study from 1998 that will be finalised by September 2005. Results from the noise mapping exercise of the airport will be incorporated to the noise indicators in a later stage.

The body contacted to get the information is AENA (Spanish Airports and Aerial Navigation), and more specifically the director of the airport of Vitoria-Gasteiz and the chef director of the control tower. The data provided includes the standard geometry of landing, the type of aircraft and the frequency of flights.

11.3 NOISE PROPAGATION DATA

The basic cartography used for noise mapping involves a three dimensional topographic map of scale 1:500. In the map terrain effects, barriers and building heights are visible.

The map was obtained from the Cartographic Unit of the Urbanism Department of the Vitoria-Gasteiz municipality.

The scale of the topographic map seemed too detailed at the beginning and even though it implies longer calculation periods when applied to the model, it was finally accepted, as it was the more recent version.

11.4 NOISE IMMISSION DATA

The starting point to calculate the noise indicators are the immision maps at the façade, which is then combined with the number of inhabitants in each dwelling.

Population data is obtained from the register and the cadastral information within the municipal GIS. There are data on the number of inhabitants per building and doorway, and on the number of floors of the buildings.

11.5 CALCULATION METHODS

The models used for the calculation of the noise emission separately by noise source are the following:

Noise source	Calculation model (Noise Emission and propagations)
Roads and streets	NMPB-Routes-96
Railways	National method from the Netherlands
Industry	ISO-9613-2
Airport	ECAC-CEAC

Figure 9 – Calculation models used to estimate the emission and propagation of the noise sources.

The acoustic model used was SoundPLAN®, which includes calculation methods recommended by the END. This model allows an easy input and output of results from and to the wider Environmental Information System.

11.6 INDICATORS AND MAPS

11.6.1 Noise maps

Two key noise maps are produced for information to the general public: a global noise map with noise contours for values for L_{den} measured at four metres above ground and the same for values of L_{night}. Maps with noise immission values for each of the noise sources (streets, roads, railway and industry) are available to the general public as well.

Other maps are done internally for assessment objectives and are usually more detailed, usually at neighbourhood level and showing a single noise source or a combination of others.

11.6.2 Noise indicators

Two kinds of indicators have been produced. The first indicator, B8, includes de following two subindictors:

Population living in streets exposed during 24h a day to outside noise higher than desired as quality objective. The indicator expresses the estimation of number of inhabitants, separately by noise source, in buildings exposed to the following range of L_{den} (dBA) values of 65-69, 70-74 and >= 75, measured at 4 metres above ground and on the most exposed façade.

Population living in streets exposed during the night period to outside noise higher than desired as quality objective. It shows the estimation of number of inhabitants, separately by noise source, in buildings exposed to the following range of L_{night} (dBA) values of 55-59, 60-64, 65-69, 70-74 and >= 75, measured at 4 metres above ground and on the most exposed façade.

These subindicators are part of the European Common Indicators set, they feeds the Local Agenda 21 and allow comparison with other EU municipalities. The indicators represent the most dominant noise source in each specific area. Streets and roads are

considered as a single noise source. Calculations are done at a single building façade height (4metres).

The purpose of the second indicator, the **Indicator on local noise management (ILNM)**, is to serve for the noise assessment and management process at the municipality. The same as above, there is a global ILNM, for all noise sources, and four subindicators that present the results separately by noise sources (streets, roads, railway and industry). Another particularity of this indicator is that streets and roads are considered separately in two different subindicators. Even if the noise source is the same this allows the design of different solutions to each type of road traffic. Calculations on noise immission levels are done at various building façade heights.

11.7 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

The main difficulty encountered has been data compilation from other services or administrations.

The opinion of the noise responsible at the Environment Department of the municipality is explained as follows. Generally speaking data providers do not yet see the importance of sharing the information for the benefit of both parts. Some of them are not always keen on providing the data in a certain format and in a more structured way. A process of awareness raise on the importance to map noise is being done at many levels. Noise mapping should not be perceived as a single task of the Environmental Department but should be regarded as an active and useful tool for the management of the noise sources and urban planning. The stress should not be given to the measuring part but to the behaviour of the noise sources and the land uses around them. A change in the mentality of all the stakeholders involved in urban planning and a stronger legislation that would establish noise permissiveness levels would help in reducing the number of people affected by noise.

The main lesson learnt is that noise mapping, if aimed at becoming more than a pure measuring exercise, is a very complex process that needs more time than expected.

Only 40 to 50% of the final objectives are accomplished with the current mapping state. The update of the map should be ideally done every year and more accuracy is intended. Agreements with the data providers are being done in order that they provide regular data at a yearly basis during the third semester of the year.
The final aim is that noise mapping becomes a flexible tool to be used as a usual management tool.

12 CYPRUS CASE STUDY

12.1 INTRODUCTION

The noise data available were collected during a three-year project partly funded under the LIFE program of the EU.

12.2 MEASUREMENTS METHODS

The noise data collected include noise readings from 30 pilot study areas in the city of Nicosia, the city of Limassol and the area around Larnaca airport (International airport of Cyprus). The data are available in electronic form (24 hours measurements) and are stored under the Microsoft Excel Software. Private companies that established a joint venture collected the data. Two of them were local, the third Austrian.

12.3 INDICATORS AND MAPS

In four areas, noise contour maps were prepared. In all other areas only the noise readings were noted. Questionnaire surveys were conducted in all areas to identify the perception of the public with regards to the extend of noise pollution. A statistical analysis of the data collected was carried out and dose (noise) response graphs were prepared for the selected areas.

12.4 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

The following are the comments from the noise-mapping responsible at the Cypriot Ministry of the Environment.

The process of data collection was time consuming. The traffic data in the areas examined were not available most of the time, therefore traffic counts had to be carried out.

The population density in the areas examined was not always known, therefore various assumptions had to be made. Weather conditions sometimes hindered collection of data. Ground survey maps were not digitally available to enable the preparation of noise maps.

Environmental noise is indeed a problem which the people that live or work in the cities face every day. In Cyprus, most of the cities (agglomerations) have a population lower than 250.000 inhabitants. The EU might consider decreasing this limit.

In the Directive, issues concerning noise coming from entertainment establishments could also be covered, as this source is more problematic for Cyprus when compared to other noise sources, such as railways, which do not exist in Cyprus.

Although noise mapping is a very time consuming process, it is nevertheless a very useful tool in order to convince decision–makers to address noise pollution and its sources.

13 MADRID

13.1 INTRODUCTION

The END was transposed to the Spanish legislation and as a result the Noise Law 37/2003 came into force.

Existing noise-mapping methods were examined before deciding what was the best option for Madrid.

The opinion of the noise experts in Madrid is explained in this paragraph. Current noise mapping tools based on both noise propagation models and noise source emission models show clear deviations when they are applied to urban agglomerations due to various factors. The expected behaviour of the road traffic in cities from the models does not match up with the real situation. Moreover, urban traffic management elements slightly modify the acoustic behaviour. It is also difficult to include other urban noise sources other than road, rail and industry and the same for the inclusion of reference meteorological conditions, especially those related to wind. On the other hand, the use of permanent noise monitoring systems through control networks uses a great amount of economic and material resources. Taking into account that results are to be considered provisional at the light of possible modifications of the legislation the conclusion was reached that a cartography based solely on measuring was not feasible for big agglomerations.

The Department of Environment and City services of the Madrid Municipality set up a pioneer mobile noise measurement system. In the origin of this system are the first environmental noise monitoring networks that were installed around airports to control noisy airplane operations.

Beginning 1994 City Council of Madrid made a research for testing a Noise Monitoring Network with the purpose to have a deeper knowledge on the evolution of urban environmental noise and to provide information to town planning responsibles and citizens. Six terminals placed at selected sites formed Madrid's experimental first network. After one year running, the available information was enough to achieve a more precise knowledge about noise affection produced by specific facilities and activities. More than 31 millions of LAeq 1s samples from each terminal were evaluated and the positive results from this exercise were a motivation to increase the number of terminals.

Finally, the Department of Environment and City Services of Madrid's municipality designed a tool based on an "Acoustic Pollution Surveillance Network" with 30 stations. Moreover, the system includes a calculation tool that is able to extend the information obtained in the sample points to the rest of the territory following the principles of acoustic propagation. This procedure allows updating noise maps in a much faster way, saving one third of time expenditure and, at least, 25% of the expenses.

13.2 MEASUREMENT AND CALCULATION METHODS

The noise-mapping tool for Madrid is called "Dynamic Updating System of the Acoustic Map of Madrid" SADMAM.

SADMAM includes three small cars (Smart Pure 55) furnished with (see annex 13.2):

- Noise measurement systems: Brüel & Kjær noise monitor (model 3597 and open spaces microphone Brüel & Kjær model 4184);

- A system for information storing, with GPS localisation systems in order to exactly georeference the noise measurement site (GPS Garmin 176C);

- A telecommunication system that allows sending these data to the server (Pneumatic mast Clark model QT4M and hoist bomb model QT 9256)

Data from the mobile stations are sent to the Data Processing Station through a GSM mobile telephone system. The application Brüel & Kjær 7802 is responsible for managing the communications and data storing. Once data are received, they are validated and stored in a database.

In addition to the noise levels obtained from the mobile stations, a working report is made for each measurement on the conditions during the measurement, a description of the area, as well as a list of the noise emission sources that are affecting the area. This report allows an adjustment of the values and the conditions to the model, adapting it to the acoustic reality of the area.

The historical analysis of the data obtained from the "Acoustic Pollution Surveillance Network" allows obtaining noise level temporary evolution profiles from various areas in Madrid. From these values an annual mean is obtained. The short-term measurements from the mobile network (at least four hours) are projected on the corresponding evolution curve obtained from these profiles to obtain new annual values. These annual values are used in the adjustment process of the noise propagation model.

Once the measured noise levels are obtained and processed, the mapping process continues with the use of a digital model. The model chosen is the Brüel & Kjær LIMA 7812C model, which follows the requirements of the END.

The data needed to feed the model is extracted from digital data, avoiding as much as possible manual digitalisation.

The characteristics of the digital cartography applied are as follows:

- Scale: 1:1000
- Surface covered: 65.000 Has
- Projection: Universal Transversa Mercator (UTM)
- Support Network: Topographic Network of Madrid (2.700 vertex)
- Capture: Restitution of the flight 1:8000 from 2001
- Field revision from 2001
- Structure: 117 codified levels (layers)
- Digital format: DXF files in sheets (1168 sheets)

In addition to all the above-mentioned data, the data obtained from the measurement points is also included in the model. LIMA model calculations assign the corresponding sound power to each noise source. Once the needed adjustments are done, the model is ready to calculate the grids at a height of 4 m above ground.

The grid density depends on the resolution and use of the noise maps. Global noise maps for agglomeration need a less detailed grid than those for the delimitation of sensitive areas or those needed for noise reduction planning in certain areas.

After several tests, the use of three different grid size units was established: 50m, 25 m and 10m. The 10 m grid is used to obtain cartographic results at a scale of 1:5.000. With the 25m grid the resulting scale is 1:10.000. The 50 metres grid performs two functions. On the one hand, it verifies the propagation in a relatively short time and, on the other hand, it shows large surfaces where a low level of detail is required.

Each map is integrated into a Geographic Information System (GIS), using the ESRI, Arcview Version 9.0 tool (see annex 13.2). It allows the combination of noise data with other various layers. The calculated noise values are also stored in a general database to allow an easy access or publication.

13.3 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

Experts from the Madrid municipality concluded that the hybrid philosophy of combining real measurements and model calculations results in maps with much lesser mistakes than those obtained exclusively from models and at a much lesser time and expenditures than those obtained solely from measurement.

14 PRAGUE CASE STUDY

14.1 INTRODUCTION

The City of Prague has a long-term experience in the noise map development.

Data on noise in urban environment has been obtained through direct measurements, by means of model calculations or using a mixture of both. Each method has its advantages and drawbacks. The measurement provides more accurate data and reflects the real noise level from all sources of noise at the locality monitored. Performance of the measurement over a larger area is, however, very financially demanding. The modelling is limited not just due to the calculation method employed, yet most of all by availability of input data. On the other hand, it enables making of qualified assessments of expected impacts of planned development and transport measures.

Long-term regularly repeated noise level measurements at selected sites of Prague were carried within two different programs. Several maps were produced in the last years using GIS and modelling methods.

1) **Environmental Information System (IOŽIP)**

In 2000 time series of regular noise level measurements within the system of IOŽIP continued at eight sites in Prague. These are four pairs of sites – always one "quiet" and one "noisy". The measurements are always performed at the same time for 24-hour period with printed records of monitored quantities at every hour and simultaneously carried out summation of traffic (at sites near a road, i.e. the "noisy" ones). The monitoring has been performed since 1984. In latest years the scope of the monitoring was very reduced due to financial reasons (it has been performed twice a year only) and in 2001 is was disrupted due to reorganising of the IOŽIP system.

2) **National programme "Environmental Monitoring related to the Population Health" (SZÚ)**

In 2000 the Public Health Service carried out regular measurements for the monitoring performed by the State Health Institute. These measurements have been performed since 1994 at four selected sites (also pairs of sites – "quiet" one and "noisy" one in a certain City areas). As representatives of noisy streets of Vinohradská, Prague 2, Koněvova, Prague 3, and Vršovická, Prague 10 were selected. As the representatives of quiet sites streets of Moravská, Prague 2, Pod lipami, Prague 3, and Bečvářova, Prague 10 were chosen. At each of these sites 24-hour long measurements are carried out five times per year and the annual result is presented as arithmetic average of measured readings (due to their low scatter).

3) Between 2000 and 2001 the **Project of the Development of the Noise Map of Automotive Traffic in Prague** was delivered using modelling and GIS technology and obtaining the subsequent assessment of the population noise nuisance.

14.2 CALCULATION METHODS

Modelling was only used to produce the maps under the Project of the Development of the Noise Map of Automotive Traffic in Prague.

An updated version of the HLUK+ software in the "HLUK+MAPA" (NOISE + MAP) setup was used for the production of the noise map of Prague. The results were subsequently exported to the GIS system that produced ultimate map outputs.

The core information used by the mathematical model is existing territorial and automotive traffic data contained in the GIS system and includes: road surface types, facade noise absorption coefficients, height of buildings, height of hedges and trees,

location and height of walls. These data followed a necessary transformation of the data from the GIS environment to the HLUK+ (NOISE+) program.

Road data was obtained from ÚDI Praha (Institute of Transportation Engineering of the city of Prague).

L_{Aeq} values were calculated for the whole territory of Prague overlaid with a regular grid of points, with a total of 85,907 calculation points.

All calculations for the automobile traffic noise map were obtained using 3-D version of the HLUK+ software Calculations results are related to points located at 4 metres above ground and 2 metres from facades of premises, which face the roads and for which input data necessary for the calculations of the LAeq values were known. The calculations included all premises within 120-metre wide, both direction zones along the roads considered.

14.3 INDICATORS AND MAPS

In recent years the Institute of Municipal Informatics of the City of Prague (IMIP) implemented larger projects focused on development of the following noise maps:

- **Road Traffic Noise Map (HMAD)** – Shows the equivalent noise level in the network of selected roads based on short-term measurements using a network of about 500 sites. The map was worked out in five-year intervals within the period 1976 to 1996.

- **Map Load Distribution Maps (NLDM)** – NLDMs show contour lines of daytime equivalent noise levels LAeq (dB(A)) on facades of especially residential buildings and other protected buildings, the contour line interval being 5 dB(A).
  The maps summarize results of long-term measurements with a 24-hour cycle, short-term measurements (generally up to one hour) and calculated noise level based on engineering and traffic load information.
  The maps show the noise situation over a large area. To achieve the required degree of accuracy a sufficient number of measurements must be made. For each administrative district there are tens of long-term and hundreds of short-term measurements (for example, Prague 9 required 38 long-term and 380 short-term measurements).
  The boundaries of the different areas of survey do not necessarily coincide with those of administrative districts. Available funding and measurement assets determine the area of mapping. Priority was assigned to the central part of the city, (City parts Prague 1 to Prague 10), which was carried out stepwise between 1992 and 1997.

- **Map on the analysis of the population noise nuisance**: In 1998 the assessment of noise nuisance to the population was made on the basis of these maps using GIS technology, using a combination of measured and model calculated data.

- **The Area Road Traffic Noise Map on the Territory of Prague 2** was developed in 1998 in order to prove potential for the development of a noise map only on the basis of model calculations (see annex 14.3).

- **Calculated noise maps of automobile and tramway traffic in Prague in 2002**.
  These maps were developed due to co-operation of the Department of Transport Development and the Department of Informatics of the Prague City Hall, Public Transport Company of Prague, and Technical Administration Service of Roads. The maps show contour lines of daytime equivalent noise levels LAeq (dB(A)) on facades of especially residential buildings and other protected buildings, the contour line interval being 5 dB(A).
  The maps summarize results of long-term measurements with a 24-hour cycle, short-term measurements (generally up to one hour) and calculated noise level based on engineering and traffic load information.

Calculated noise map of automobile traffic in nighttime in Prague was done in 2004.

14.4 PROBLEMS ENCOUNTERED AND LESSONS LEARNT

Outputs of a study made in Prague confirm that it is feasible to produce a traffic-generated area noise map of Prague (for both daytime and nighttime periods) based on a mathematical formula. Understandably, the extent of available input data (e.g. the degree of detail of the traffic data network) is a limiting factor when preparing calculation-based maps. A promising solution seems to be a combination of simulation and mathematical methods on the one hand, and supplementary noise measurements on the other hand, so that updated input information can be quickly presented in traffic-generated noise maps for large areas.

15 CONCLUSIONS

When writing the present report some limitations had to be faced. As the provision of information from municipalities, regional authorities, ministries and private companies was on a voluntary basis, the quality and amount of information was in a very limited extend controlled by the ETC/TE.

This has resulted in a very heterogeneous information input, which does not allow an easy comparison among case studies. It is important to mention, however, that the general attitude from noise experts has been very positive and helpful towards providing information for the report.

Another limitation during the last month of the preparation of the report was the low availability of experts due to the summer vacation period.

Most cities and regions had previously a tradition of noise mapping since the 70's or 80's. There is a trend towards using noise modelling methods during the last years in reaction to the END. For a few others complex noise mapping is a new activity inspired by the transposition of the END to their respective Member States.

Two case studies have mentioned to carry out their noise mapping activities under an EU LIFE program.

Whilst most of the case studies have used, as recommended by the END, modelling tools to produce their noise maps, three case studies (Cyprus, Madrid and Prague) have used regular direct measurements:

- In Cyprus only direct measurements are used;

- In Madrid modelling is exclusively used to extrapolate the results to a wider area;

- In Prague separate maps are produced using modelling and using measurements.

Even though the issue of what noise mapping methods would be preferable is out of the scope of this report, the discussion on whether direct measurements or modelling or a combination of both is most adequate is present in many of the reports and experts consulted. Yet there is no consensus on the topic, although the END recommends modelling because is more practical for planning purposes.

In each chapter comprehensive information is given on input noise emission, propagation and immission data. An accurate comparison of the data used is not easy because each case study uses different degrees of accuracy in data, according to the requirements of the model used. Moreover, maps based on direct measurement do not require detailed noise emission and propagation data. Yet, some general conclusions on noise data can be extracted from the report as follows.

In various case studies it is mentioned that the main part of the work, both in time and cost aspects, is devoted to data processing rather than to the calculation phase or the production of maps. Data processing includes the identification and acquisition of the databases as well as the compilation and treatment of the data.

Regarding the noise sources:

- All case studies consider road traffic as the main source of noise to be mapped.

- Railway is the second most commonly mapped noise source. In some case studies railway data is not collected either due to the absence of a railway network or because the noise impact is not considered relevant.

- Noise data from airports and industry are specifically collected in only four of the case studies.

The following is the analysis of how data was acquired:

- Most road traffic data is produced or kept at local or regional level, except in the case of Birmingham, where it was obtained from a private consultant.

- Railway data is usually in the hands of national railway institutions except, again, in the case of Birmingham, where some of the data was also held by a private consultant.

- Aircraft data is either managed by national aircraft institutions or by the local airport itself. It is worth mentioning that some airports are not willing to share their data and prefer to produce their own maps. Sometimes these maps are integrated in the general city map.

- Industrial data is obtained at regional or local level and through direct measurements, although in most of the cases it is not considered, as any data is available.

- Propagation data has a very heterogeneous origin. Usually topology maps are available among the local or regional cartographic material, sometimes even in 3D, but they are not always in a digital format. In Dublin, data on land use had to be purchased from private companies. Additional data needed might be obtained through on-ground measurements or through ortophotos. The opinion of some experts is that sufficiently accurate geographical information can be acquired but it involves cost elements in most of the cases.

- Building height data, which is not usually available, is mostly found at local level. In Dublin these data are purchased from a private company and in Vienna they are gathered through terrestrial surveys.

- Population data is mostly available at local or regional level or from national census. In Dublin population spread from the national census is also purchased from private companies.

The examples gathered illustrate a wide variety of situations and show how noise-mapping experts have managed the problems encountered with additional efforts. Solutions found to common problems are described in the following paragraphs and can be of help for other noise-mapping experts.

- When there was no existing division of the data between day and night period estimations had to be made using an approximate traffic flow distribution during day, evening and night

- Sometimes, an additional classification of roads was needed.

- Meteorological data was mostly not available, therefore a standard value was assumed.

- Industry emission levels were not available. Assumptions were made using the maximum legal emission values. When these were not existent, emergency levels were used.

- Building height was estimated through aerial photographs, through multiplying the number of floors by certain metres, or by assuming that there was a relationship between the base area of the building and its height.

- Digitalisation of the data had to be done in many cases. More efficient ways of data treatment should be found.

- Detailed geographical data on barriers, embankments, etc. was usually not available. Instead, noise experts had to make approximations or produce additional data sets. Terrestrial surveying, aerial photographs, or digitising paper format information, among others was done in these cases.

- The designation of special calm areas was obtained from mapping, ortho-photographs and in-situ observations.

Most commonly used indicators were Lden. Indicators on exposed population are presented to the public in only few case studies. In many situations indicators had to be converted from the old measurements to Lden. Most commonly used maps present noise immission contour maps or grids, both separately by source as well as all sources together. Municipalities that use measurements only show total immission maps, as they do not track the sources.

Particularly interesting opinions are included in the chapters devoted to "Problems encountered and lessons learnt". Common complaints found in almost every case study are, first, that the process of data collection, production and treatment is time and cost consuming and secondly, the there is generally speaking lack of data.

Other comments shared by some municipalities are that it is not possible to produce maps without the assistance of external expertise or additional in-house expertise in order to understand the whole process. Interdepartmental cooperation within the municipality is also crucial.

Experts also remark that other departments still do not see the importance of providing data because they do not yet see the use of noise maps as effective planning and management tools.

16 GLOSSARY OF TERMS

The following glossary includes a selection of the most commonly used terms concerning noise mapping. It does not intend to be an exhaustive list of all noise-related terms mentioned in the report.

'A' Weighting: A frequency dependant correction which weights sound to correlate with the sensitivity of the human ear to sounds at different frequencies.

Decibel (dB): A unit for measuring sound that is not absolute but is a ratio between a measured quantity and an agreed reference level. The dB scale is logarithmic and uses the hearing threshold of 20μPa as the reference level

dB(A): The unit of sound pressure level, weighted according to the A scale, which takes into account the increased sensitivity of the human ear at some frequencies.

GIS: **'Geographical Information System'**

This is a computer system specially designed to manage information with a geographical relationship. The information is stored digitally and can be represented visually as maps.

Grid: Noise calculation software is able to predict noise levels at discrete locations. One way of representing locations is to create a grid of regularly spaced noise levels at defined intervals.

LA10T: The A weighted sound level exceeded for 10% of the measurement time interval (T).

LaeqT: The notional A-weighted equivalent continuous sound level, which, if it occurred over the same time period, would give the same noise level as the continuously varying sound level. The T denotes the time period over which the average is taken, for example LAeq,16h is the equivalent continuous noise level over a 16 hour period.

Lday: The long term A-weighted average sound level over the day period (from 07:00 to 19:00 hours).

Lden: The day, evening, night level, Lden, is a logarithmic composite of the long term A-weighted day noise level, the evening noise level +5 dB and the night noise level +10dB.

Levening: The long term A-weighted average sound level over the evening period (from 19:00 to 23:00 hours).

Lnight: The long term A-weighted average sound level over the night period.

Noise/Sound: Noise is simply unwanted sound. For this reason, sometimes the two terms are used indistinctly in the report.

Noise Emission: The noise emanating from a source.

Noise Immission: The noise received at a reception point.

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18 ANNEXES

Annex 4.4. Noise map maps of Berlin

Figure 4.4.1 Environmental noise – day

Figure 4.4.2 Environmental noise - night
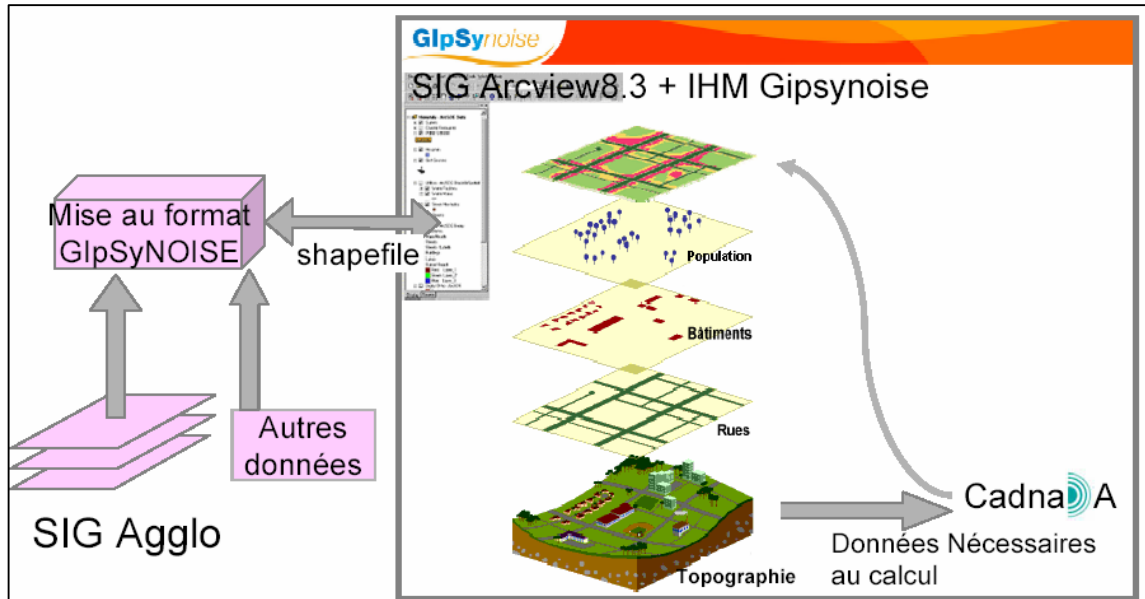

Figure 4.4.3 Over ground Rail traffic – day

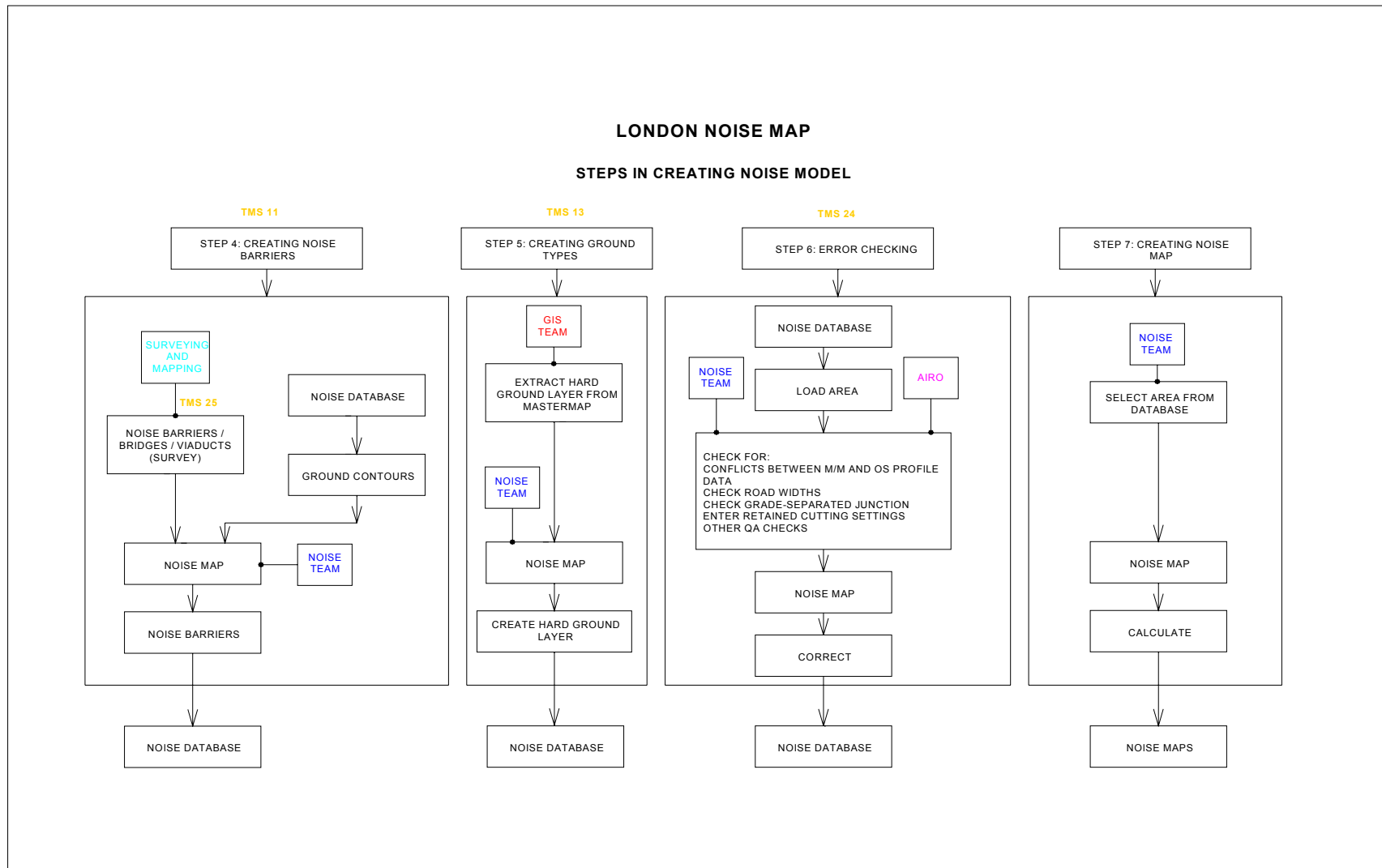Figure 4.4.4 Over ground Rail traffic night

Annex 5.6. Flow diagram of main steps taken to produce Birmingham's Noise Maps
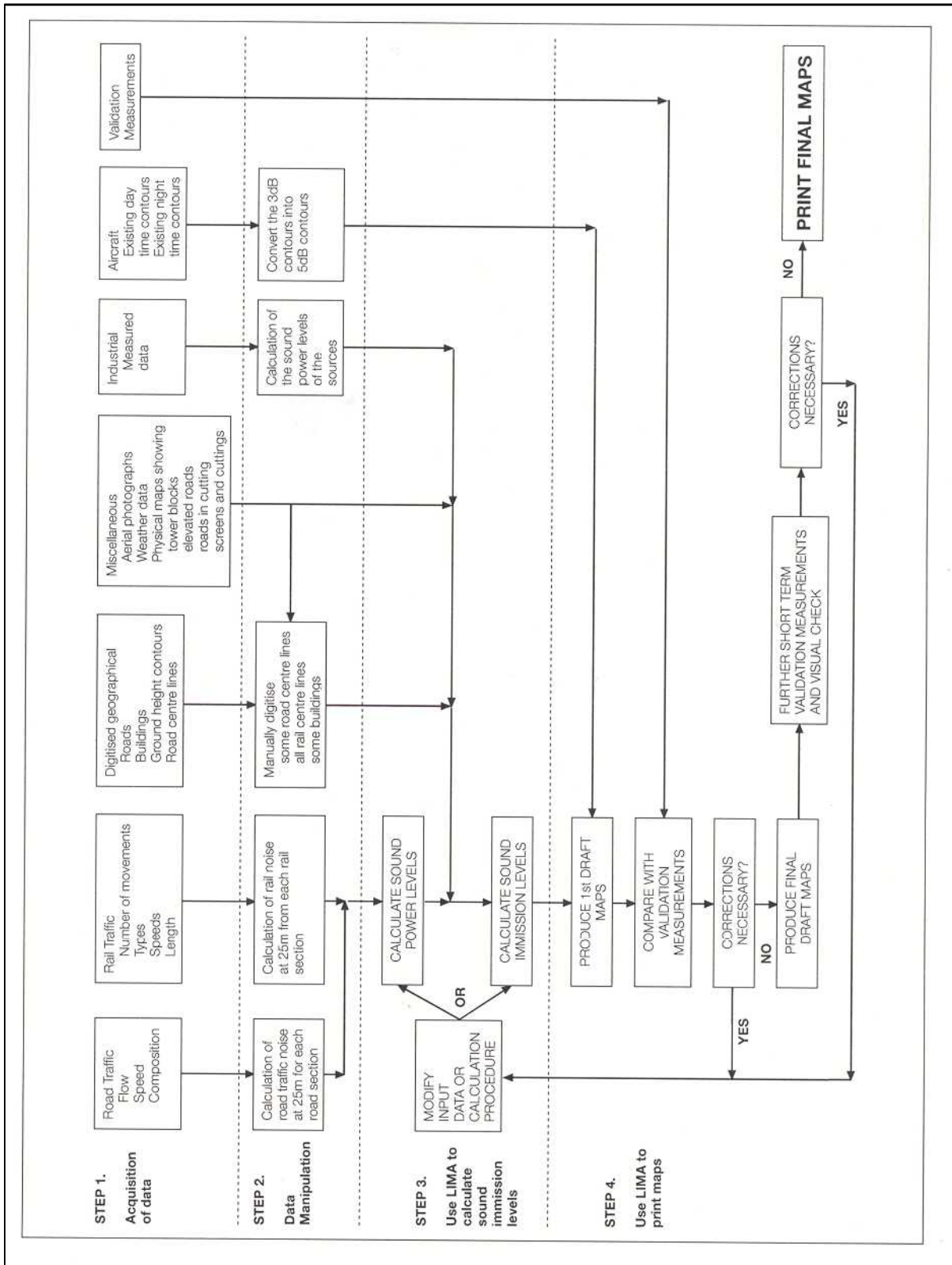
Annex 7.5 – Scheme of the GIpSyNOISE system

Annex 8.1 Flow diagram of main steps taken to produce London's Noise Maps

LONDON NOISE MAP

STEPS IN CREATING NOISE MODEL

TMS 11	TMS 13	TMS 24	
STEP 4: CREATING NOISE BARRIERS	STEP 5: CREATING GROUND TYPES	STEP 6: ERROR CHECKING	STEP 7: CREATING NOISE MAP

Column 1 (STEP 4):
- SURVEYING AND MAPPING
- TMS 25
- NOISE BARRIERS / BRIDGES / VIADUCTS (SURVEY)
- NOISE DATABASE
- GROUND CONTOURS
- NOISE MAP
- NOISE TEAM
- NOISE BARRIERS
- NOISE DATABASE

Column 2 (STEP 5):
- GIS TEAM
- EXTRACT HARD GROUND LAYER FROM MASTERMAP
- NOISE TEAM
- NOISE MAP
- CREATE HARD GROUND LAYER
- NOISE DATABASE

Column 3 (STEP 6):
- NOISE DATABASE
- NOISE TEAM
- LOAD AREA
- AIRO
- CHECK FOR:
  CONFLICTS BETWEEN M/M AND OS PROFILE DATA
  CHECK ROAD WIDTHS
  CHECK GRADE-SEPARATED JUNCTION
  ENTER RETAINED CUTTING SETTINGS
  OTHER QA CHECKS
- NOISE MAP
- CORRECT
- NOISE DATABASE

Column 4 (STEP 7):
- NOISE TEAM
- SELECT AREA FROM DATABASE
- NOISE MAP
- CALCULATE
- NOISE MAPS

Annex 8.6. Noise maps of London

Figure 8.6.1 Detail of a loud area in London
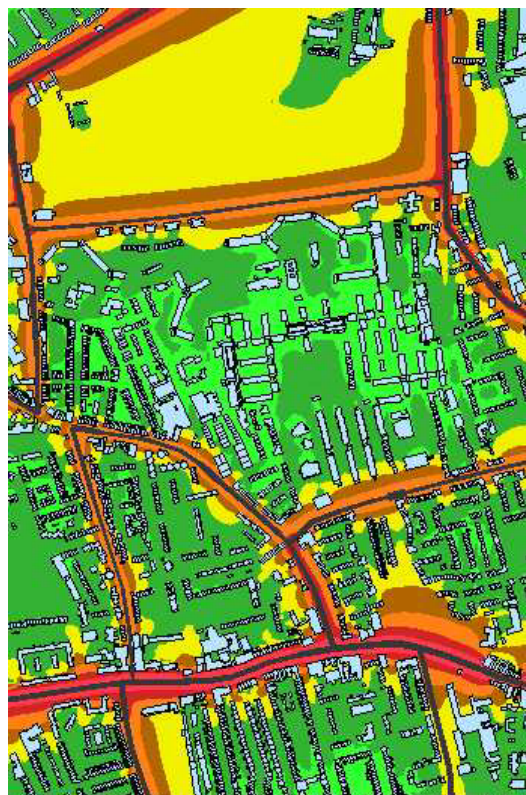
Figure 8.6.2 Detail of a quite area in London

Annex 9.6 Noise maps in Stockholm

Figure 9.6.1 Total noise map of Stockholm
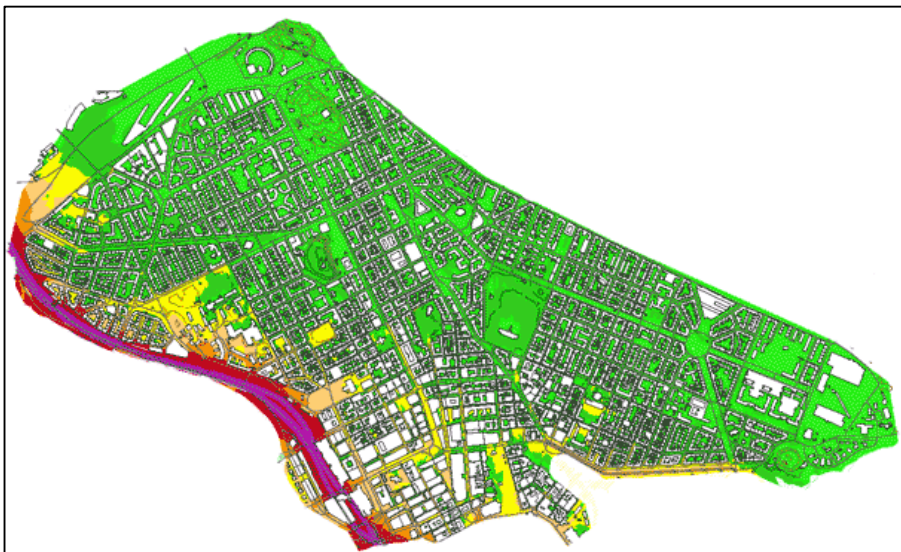
Figure 9.6.2 Rail traffic noise map of Stockholm

Figure 9.6.3. Road traffic noise map of Stockholm
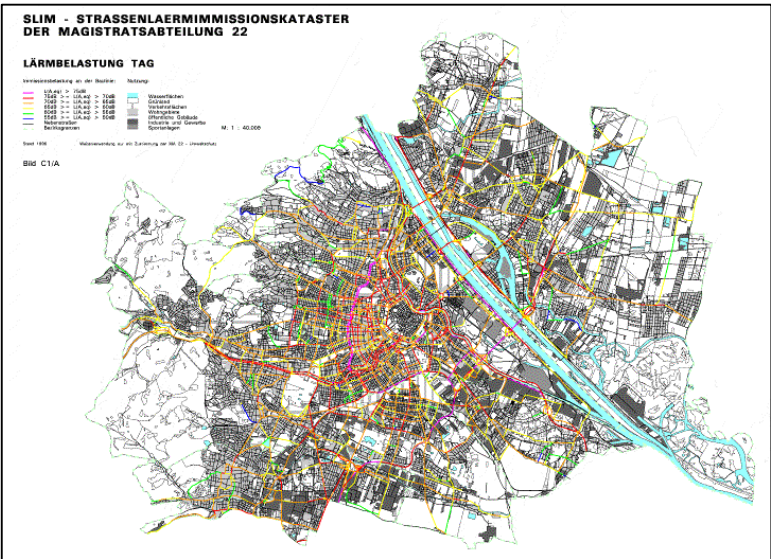
Annex 10.5. Noise maps in Vienna
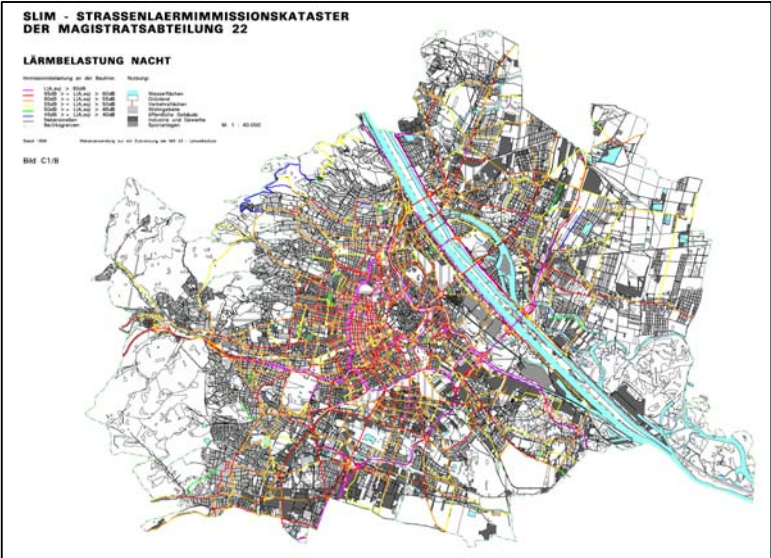

Figure 10.5.1 Road traffic map at daytime

Figure 10.5.2 Road traffic map at nighttime

Annex 13.2. SADMAM tool

Figure 13.2.1 Picture of the equipment of the SADMAM mobile stations
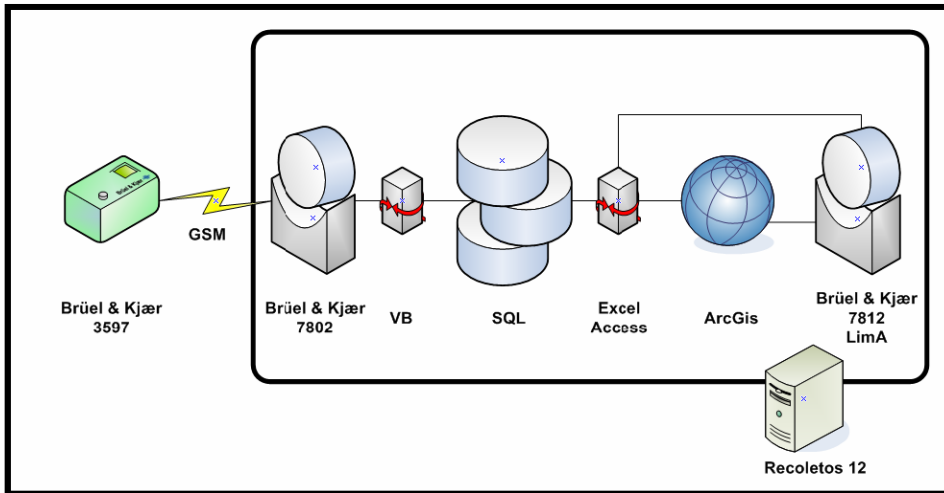
Figure 13.2.2 SADMAM functioning scheme
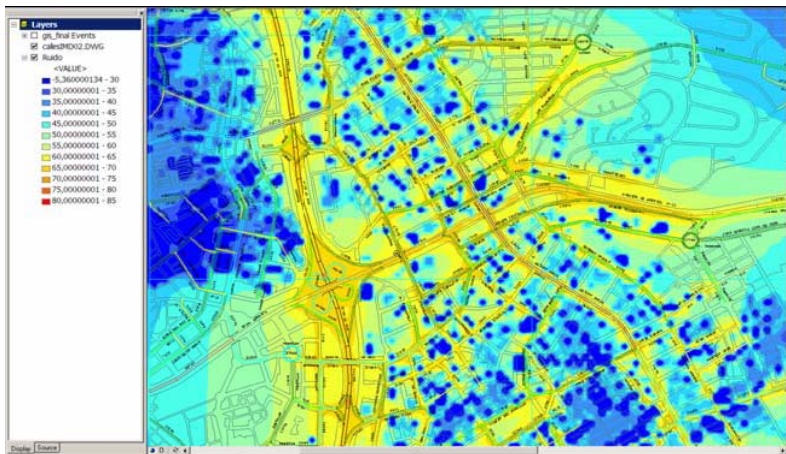
Figure13.2.3 Example of GIS integration of noise data

Annex 14.3. Noise Maps of Prague
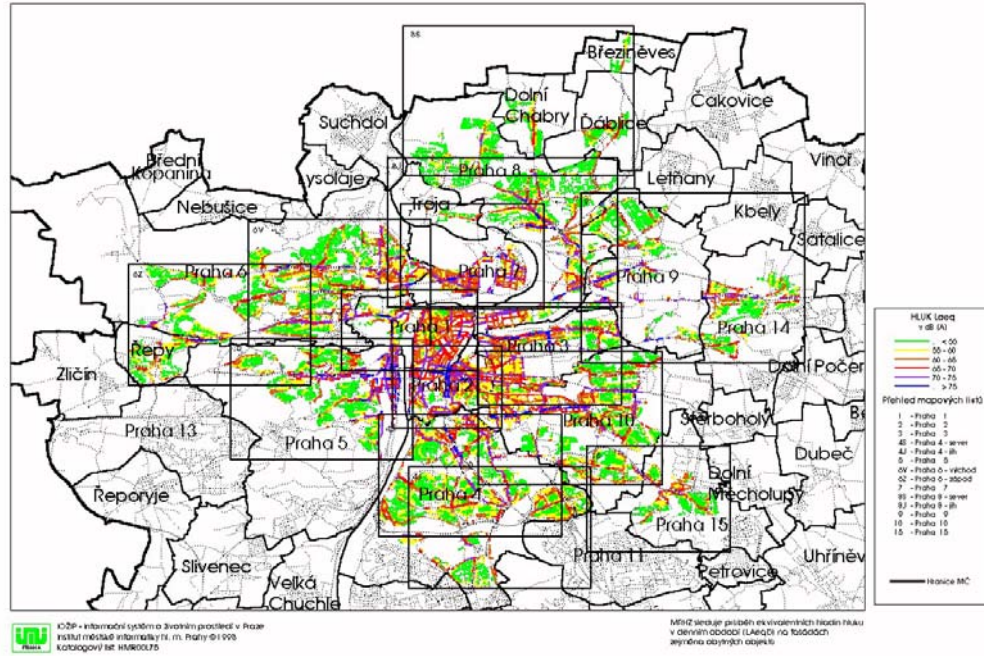
Figure 14.3.1 Map of noise load distribution in Prague
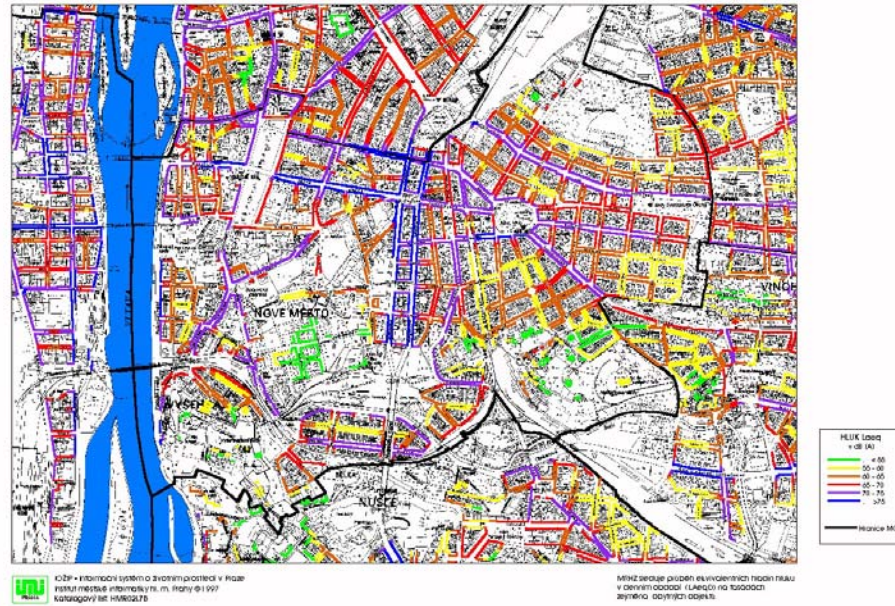
14.3.2 Number of people in urban districts by the noise level they are exposed to