Noise in Europe 2014

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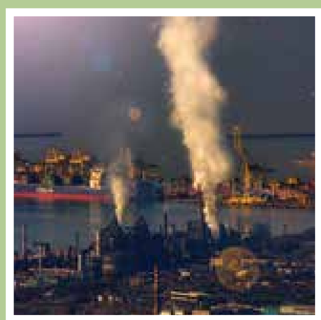

European Environment Agency

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Executive summary

Noise pollution is a growing environmental concern. It is caused by a varied number of sources and is widely present not only in the busiest urban environments, it is also pervading once natural environments. The adverse effects can be found in the well-being of exposed human populations, in the health and distribution of wildlife on the land and in the sea, in the abilities of our children to learn properly at school and in the high economic price society must pay because of noise pollution. The European soundscape is under threat and this report sets out to quantify the scale of the problem, assess what actions are being taken and to scope those that may need to be considered in the future, in order to redress the problem.

The key messages from this report are:

1. noise pollution is a major environmental health problem in Europe;

2. road traffic is the most dominant source of environmental noise with an estimated 125 million people affected by noise levels greater than 55 decibels (dB) L_{den} (day-evening-night level);

3. environmental noise causes at least 10 000 cases of premature death in Europe each year;

4. almost 20 million adults are annoyed and a further 8 million suffer sleep disturbance due to environmental noise;

5. over 900 000 cases of hypertension are caused by environmental noise each year;

6. noise pollution causes 43 000 hospital admissions in Europe per year;

7. effects of noise upon the wider soundscape, including wildlife and quiet areas, need further assessment;

8. political ambitions are high with the European Union's (EU) Seventh Environment Action Programme (7th EAP) containing the objective that noise pollution in the EU has significantly decreased by 2020, moving closer to World Health Organization (WHO) recommended levels;

9. a complete assessment and future outlook are hindered by the fact that exposure estimates reported by countries are not complete, with as little as 44 % of the expected amount of data, depending on source, being delivered in the latest reporting round;

10. lack of comparable and common assessment methods often causes significant inconsistencies in exposure estimates, between different countries, within a single country and across the two main reporting rounds.

1 Introduction

This report is the European Environment Agency's (EEA) first noise assessment report. Its purpose is to present an overview and analysis of environmental noise based upon information reported to EEA by its member countries following the requirements of the EU Directive 2002/49/EC relating to the assessment and management of environmental noise — the Environmental Noise Directive (END) (EU, 2002a).

Noise pollution has long been recognised as affecting quality of life and well-being. Over past decades it has, in addition, increasingly been recognised as an important public health issue. According to a recent WHO report on the burden of disease from environmental noise (WHO, 2011), at least 1 million healthy life years are lost every year in western Europe due to health effects arising from noise exposure to road traffic alone. Further, the WHO categorises noise as being the second-worst environmental cause of ill health, behind only ultra-fine particulate matter ($PM_{2.5}$) air pollution.

In terms of defining what is meant by environmental noise, the WHO describes environmental noise generically, as that emitted by all sources except for noise in the industrial workplace (WHO, 1999). The END is more specific in its definition, considering environmental noise as being unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic and from sites of industrial activity. It does not apply however to noise that is caused by the exposed persons themselves, noise from domestic activities, noise created by neighbours, noise at work places or noise inside vehicles or due to military activities in military areas. Some of these excluded areas, such as those related to indoor noise, are covered by other policy instruments both at national and EU level, such as those related to health and occupational safety. Harmful effects are further defined as meaning negative effects on human health.

1.1 Policy context — European noise legislation

The EU's 7th EAP 'Living well, within the limits of our planet' (EU, 2013) highlights that a majority of Europeans living in major urban areas are exposed to high levels of noise ([1]) at which adverse health effects occur frequently. It further contains the objective that by 2020 noise pollution in the EU has significantly decreased, moving closer to WHO recommended levels. In order for this objective to be achieved, it is identified that this will require implementation of an updated EU noise policy aligned with the latest scientific knowledge, and measures to reduce noise at source, including improvements in city design.

Prior to the development of the present 7th EAP, there has been more than two decades of effort to develop a coordinated EU policy on noise. The first comprehensive step was taken in 1993, with the adoption of the 5th EAP by the European Commission, titled 'Towards Sustainability'. This incorporated a declared objective that 'no person should be exposed to noise levels which endanger health and quality of life' (European Commission, 2003).

Subsequently, the Commission adopted a Green Paper on Future Noise Policy in 1996 (European Commission, 1996). This identified noise in the environment as one of the main environmental problems in Europe and concluded that in terms of past Commission policy, it perhaps had not been given the necessary priority. As a result, the Green Paper proposed a new framework for noise policy development that, in particular, identified scope for improvement in three key areas:

1. Firstly, knowledge gaps should be filled to better assess the environmental noise exposure situation in Europe. In particular, the lack of comparability between different Member States

([1]) 'High noise levels' are defined in the 7th EAP as noise levels above 55 dB L_{den} and 50 dB L_{night}.

and between different noise sources requires addressing.

2. Secondly, the public should be more informed and involved.

3. Thirdly, noise abatement should be part of an integrated strategy towards a better quality of life.

The 6th EAP 'Environment 2010: Our Future, Our Choice' stated an objective 'to achieve an environmental quality which does not give rise to significant impacts on, or risks to, human health' (European Commission, 2010). It also strengthened the concept of a knowledge-based approach to policymaking and proposed that the Commission adopt and implement a directive on environmental noise — the END.

The stated aim of the END is to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise and at providing a basis for developing Community measures to reduce noise emitted by the major sources, in particular road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery.

It requires the following actions to be implemented in order to achieve that aim:

- the determination of exposure to environmental noise, through noise mapping, by methods of assessment common to the Member States;
- ensuring that information on environmental noise and its effects is made available to the public;
- adoption of action plans by the Member States, based upon noise mapping results, with a view to preventing and reducing environmental noise where necessary and particularly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality where it is good.

Accompanying the END are a number of other legislative measures that aim to address or control noise at source. Many of these noise-management measures are based upon EU internal market objectives, and from the 1970s onwards focused upon establishing harmonised maximum noise limits for motor vehicles and household equipment, such as appliances, outdoor tools and other noise-generating products. Others address noise from specific sectors such as aviation through establishing procedures for the introduction of noise-related operating restrictions (EU, 2002b), or for industry by requiring an integrated approach be taken for the permitting of industrial facilities that takes into account the whole environmental performance of the plant, including noise (EU, 2010). Today, European environmental noise legislation covers a wide range of product types and sources (see Annex 1).

1.2 Why noise is a problem — impacts arising from exposure to environmental noise

A number of adverse health impacts, both direct and indirect, have been linked to exposure to persistent or high levels of noise. Night-time effects can differ significantly from daytime impacts — the WHO reports an onset of adverse health effects in humans exposed to noise levels at night above 40 dB (WHO, 2009).

Box 1.1 Noise indicators in the END

The END defines a number of noise indicators to be applied in noise mapping and action planning. These indicators represent a physical scale for the description of environmental noise, which has a relationship with its harmful effects. The two most important indicators are:

1. L_{den}: the day-evening-night–level indicator designed to assess annoyance;

2. L_{night}: the night-level indicator designed to assess sleep disturbance.

These indicators are to be applied to noise mapping exposure assessments beginning at 55 dB for L_{den} and at 50 dB for L_{night}. The END provides technical definitions for these indicators in its Annex 1. It also suggests supplementary noise indicators for use in cases where it may be advantageous to use special noise indicators and related limit values.

Figure 1.1 illustrates how exposure to noise affects health and well-being. Within a part of a population exposed to elevated levels of noise, stress reactions, sleep-stage changes, and other biological and biophysical effects may occur. These may in turn lead to a worsening of various health risk factors such as blood pressure. For a relatively small part of the population, the subsequent changes may then develop into clinical symptoms like insomnia and cardiovascular diseases that, as a consequence, can increase rates of premature mortality.

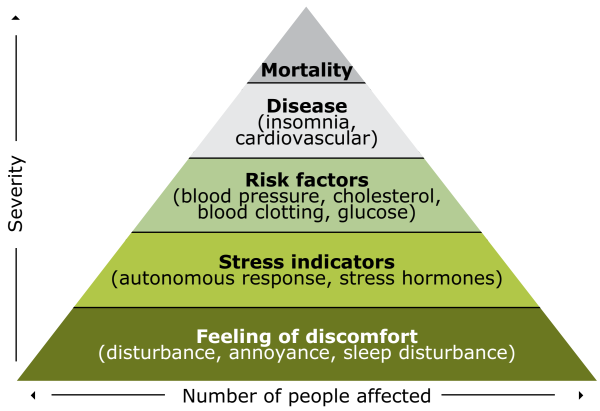
1.2.1 *Sleep disturbance*

Uninterrupted sleep is known to be a prerequisite for good physiological and mental functioning of healthy persons (WHO, 1999); however, sleep disturbance is considered to be one of the effects arising from exposure to environmental noise.

Noise can cause difficulty in falling asleep, awakening and alterations to the depth of sleep, especially a reduction in the proportion of healthy rapid eye movement sleep. Other primary physiological effects induced by noise during sleep can include increased blood pressure, increased heart rate, vasoconstriction, changes in respiration and increased body movements (WHO, 1999).

Exposure to night-time noise also may induce secondary effects, or so-called after-effects. These are effects that can be measured the day following exposure, while the individual is awake, and include increased fatigue, depression and reduced performance (Pearsons, 1998).

Figure 1.1 Pyramid of noise effects



Source: Babisch, 2002, based on WHO, 1972.

1.2.2 *Cardiovascular and physiological effects*

Noise exposure can increase blood pressure and vasoconstriction. After prolonged exposure, susceptible individuals may develop more permanent effects such as hypertension and heart disease (WHO, 1999).

Ischaemic heart disease (including myocardial infarction) and hypertension (high blood pressure) have been much investigated with respect to noise. The hypothesis that chronic noise affects cardiovascular health is due to the following facts (biological plausibility):

1) Laboratory studies in humans have shown that exposure to acute noise affects the sympathetic and endocrine system, resulting in nonspecific physiological responses (e.g. heart rate, blood pressure, vasoconstriction (the narrowing of the blood vessels), stress hormones, ECG).

2) Noise-induced instantaneous autonomic responses do not only occur in waking hours but also in sleeping subjects even when no EEG awakening is present. They do not fully adapt on a long-term basis although a clear subjective habituation occurs after a few nights

3) Animal studies have shown that long-term exposure to high noise levels leads to manifest health disorders, including high blood pressure and 'ageing of the heart'.

4) Although effects tend to be diluted in occupational studies due to the 'healthy worker effect', epidemiological studies carried out in the occupational field have shown that employees working in high noise environments are at a higher risk of high blood pressure and myocardial infarction.

The general stress theory is the rationale for the non-auditory physiological effects of noise. Noise affects the organism either directly through synaptic nervous interactions, or indirectly through the emotional and the cognitive perception of sound. The objective noise exposure (sound level) and the subjective noise exposure (annoyance) may both be interacting predictors in the relationship between noise and health endpoints.

Short-term changes in circulation including blood pressure, heart rate, cardiac output and vasoconstriction as well as the release of stress hormones, including adrenaline and noradrenalin and cortisol have been studied in experimental settings. Classical biological risk factors have been shown to be elevated in subjects who were exposed to high levels of noise. Acute noise effects do not only occur at high sound levels in occupational settings, but also at relatively low environmental sound levels when certain activities such as concentration, relaxation or sleep are disturbed (EEA, 2010).

1.2.3 Mental health effects

An exact causal relationship between noise and mental illness remains ill-defined, and it may well be that noise is just one of many factors affecting mental health. The WHO has previously suggested that environmental noise intensifies the development of latent mental disorder. Symptoms cited include anxiety, stress, nervousness, nausea, headaches, instability, argumentativeness, sexual impotency and mood changes. Studies on the use of drugs such as tranquillisers and sleeping pills, on psychiatric symptoms and on mental hospital admission rates do however suggest links between environmental noise and adverse effects on mental health (WHO, 1999).

1.2.4 Annoyance

Annoyance has been defined as a feeling of displeasure associated with any agent or condition known or believed by an individual or group to adversely affect them (Koelega, 1987). In addition to annoyance following exposure to prolonged high levels of environmental noise, people may also feel a variety of other negative emotions, for example feelings of anger, depression, helplessness, anxiety and exhaustion.

1.2.5 Cognitive impairment

The detrimental effects of environmental noise on the learning abilities of children have also been demonstrated by various studies. In particular, it has been found that noise from airports in the vicinity of schools has adversely affected the reading ability of the pupils (Hygge et al., 2002). Similarly, the effect of road traffic and aircraft noise has exhibited a detrimental impact on both the health and cognitive abilities of children (Stansfeld et al., 2005).

1.2.6 Impacts on wildlife

There is increasing scientific evidence regarding the harmful effects of noise on wildlife (Dutilleux, 2012). Whether in the terrestrial or marine environment, many species rely on acoustic communication for important aspects of life, such as finding food or locating a mate. Anthropogenic noise sources can potentially interfere with these functions and thus adversely affect species richness, reproductive success, population size and distribution. Noise pollution is also known to widely affect behaviour in some species.

The requirement for identification and protection of quiet areas in association with the END also presents an ideal synergy with the need to protect species vulnerable to noise pollution and areas of valuable habitat identified by other European assessments, such as Natura 2000 protected sites.

1.2.7 Economic impacts

When the European Commission presented its Green Paper on Future Noise Policy in 1996, it estimated the annual economic damage to the EU due to environmental noise as potentially ranging from EUR 13 million to EUR 30 billion (European Commission, 1996). The Green Paper considered that the key elements contributing to these external costs were a reduction of house prices, reduced possibilities of land use, increased medical costs and the cost of lost productivity in the workplace due to illness caused by the effects of noise pollution.

Subsequently, in its 2011 report on the implementation of the END, the European Commission estimated the social cost of rail and road traffic noise in the EU as being EUR 40 billion per year, of which 90 % was related to passenger cars and goods vehicles (European Commission, 2011).

A number of Member States have made their own analyses of the costs associated with exposure to noise. In Sweden, the social cost for road traffic noise in that country was estimated as being over SEK 16 billion. The cost of railway noise was estimated to be SEK 908 million per year, while aircraft noise was estimated to cost the Swedish economy SEK 62 million per year (Naturvårdsverket, 2014).

In the United Kingdom, the Intergovernmental Group on Costs and Benefits estimated the social cost of environmental noise in England alone as GBP 7 10 billion per annum. Placing it at a similar magnitude to road accidents (GBP 9 billion) and significantly greater than the impact of climate change (GBP 1–4 billion).

The most severe health effects of noise such as the impact upon cardiovascular disease were estimated in the same report as costing GBP 2–3 billlion per year. Effects on amenity, which reflects consumer annoyance through noise exposure was estimated as costing GBP 3–5 billion each year. Furthermore, the impact upon productivity relating to areas such as reduced work quality as a result of tiredness or noise acting as a distraction was estimated to cost GBP 2 billion every year (Defra, 2008).

In Switzerland, the external costs of transport noise have been estimated as approximately EUR 1.5 billion, of which 81 % is attributable to road traffic, 15 % to railways and 4 % to aircraft noise (FOEN, 2010).

There are presently two main methods employed to estimate the economic benefit associated with projects that reduce noise levels: contingent valuation and hedonic pricing.

Concerning the former approach, a European Commission working group earlier developed a position paper 'Valuation of noise' (EC, 2004) based on the willingness-to-pay principle, drawing upon data from Navrud (2002). The paper recommends the use of a benefit of EUR 25 per household per decibel per year above noise levels of L_{den} = 50–55 dB. Even though this figure has been criticised by some as being too low, it appears that most noise-abatement measures do deliver a positive cost/benefit ratio (EEA, 2010).

Hedonic pricing data come from studies of real estate markets, for which it is found that properties exposed to higher noise levels will typically have a lower value on the market than similar buildings exposed to lower noise levels. This relationship is well documented for residential houses (for which there is extensive literature) and probably may be similar for commercial office buildings. A best estimate is that house prices lose 0.5 % of their value per decibel over 50–55 dB L_{den}. The range of research results is between 0.2 % and 1.5 %, with a tendency for higher values for aircraft noise (EEA, 2010).

In Denmark it is estimated that there are several hundred premature deaths each year due to road traffic noise. A subsequent cost/benefit analysis indicates that widespread installation of acoustic glazing in dwellings affected by noise levels above 68 dB can deliver an overall socio-economic gain of DKK 12.7 billion over a 20-year period, equivalent to DKK 958 million per year. For dwellings with a noise exposure of more than 73 dB there is a total socio-economic gain of DKK 3.2 billion over a 20-year period, equivalent to DKK 245 million per year. With more limited uptake for dwellings with a noise exposure of more than 76 dB there is a total gain of DKK 422 million, equivalent to DKK 32 million per year (Miljøstyrelsen, 2013).

The drive to protect quiet areas from increases in noise pollution has led to the economic valuation of 'quiet'. A study in the United Kingdom indicated that protection of quiet areas in the major cities of England could be valued at as much as GBP 1.4 billion per year to the economy (Defra, 2011).

1.3 Contents of this report

The following chapter, Chapter 2, describes the data sources and methodology used in this assessment, with Chapter 3 presenting the main noise exposure assessment results based upon official information reported by the EEA member countries. Chapter 4 presents the findings of a health impact assessment, describing the latest health impact estimates associated with environmental noise exposure in Europe. A description of selected actions being undertaken to mitigate noise exposure is given in Chapter 5. Finally, Chapter 6 presents the general observations and conclusions arising from the assessment.

Accompanying the report are country-specific breifings, presenting selected aspects of data reported to the EEA. The briefings are published separately and may be accessed at http://forum.eionet.europa.eu/nrc-noise/library/country-fiches-2014.

The Noise Observation and Information Service for Europe (NOISE) is the database of END-related information maintained by the EEA. This report is based upon that data; however, it should be noted that the NOISE database is updated periodically and, therefore, may not necessarily reflect the data presented in this report at the time of writing. The NOISE database is accessible at http://NOISE.eionet.europa.eu.

2 Data and methodology

The assessment performed in this report is based upon information from the EEA's member countries obtained using modelling and measurement methods and reported to the EEA up to 28 August 2013. The current state of knowledge on noise in Europe is largely based upon the noise mapping data related to the END, which is derived from large-scale modelling exercises at national, regional and city scales. Due to the scheduled timing of deliveries under the END reporting context, this data could however, at a given point in time, be up to six or more years out of date. The following assessment is based mostly upon this modelled data, but attention is drawn to efforts to utilise more up-to-date information on noise, from long-term measurement stations and mobile devices capable of measuring and rating noise to near-real-time capacity.

Box 2.1 What is noise mapping?

Noise pollution is very often all around us, particularly in urban environments, but it can be difficult to fully understand what cannot be visualised at first hand. Noise mapping offers a way to see the unseen.

According to the END, noise mapping means 'the presentation of data on an existing or predicted noise situation in terms of a noise indicator, indicating breaches of any relevant limit value in force, the number of people affected in a certain area, or the number of dwellings exposed to certain values of a noise indicator in a certain area'.

It also defines a strategic noise map as 'a map designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area'. Furthermore, Annex IV of the END sets out the minimum requirements for strategic noise mapping.

Figure 2.1 Noise map for road traffic L_{den} in Dublin, 2012

Source: Dublin City Council, 2012.

Where data are available, the analysis covers up to 34 countries, the 33 EEA member countries plus the former Yugoslav Republic of Macedonia. This includes assessments for up to 471 urban areas, referred to as agglomerations, in which road, rail, airport and industrial noise are considered. The assessment encompasses 91 airports, 181 767 km of roads and 40 066 km of railways, outside of cities. The scope of the analysis extends only to terrestrial exposure to airborne sound as it affects the human population, although acknowledgement is given to the links between noise and its impact on wildlife both on land and in water.

2.1 Information reported under the END

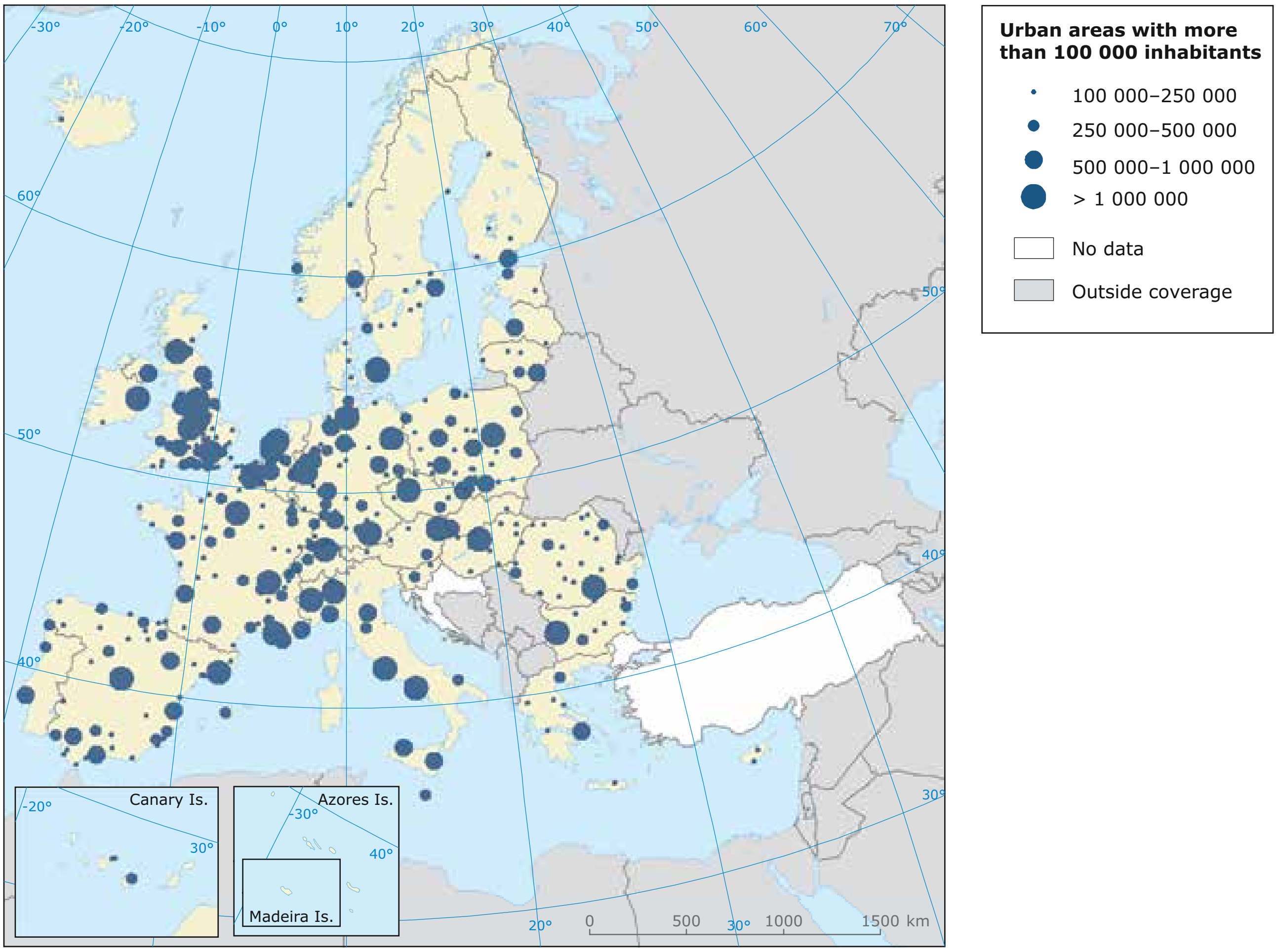
2.1.1 *Strategic noise mapping*

One of the objectives of the END is to establish a common approach to assess the exposure to environmental noise throughout the EU. For this purpose, a set of common noise indicators is defined in the directive, addressing both annoyance and sleep disturbance (see Box 1.1). On the basis of these indicators, the END requires Member States to produce strategic noise maps for all major roads, railways, airports and agglomerations on at least a 5-yearly basis, starting from 30 June 2007 (see Maps 2.1 and 2.2). The strategic maps must satisfy minimum requirements as listed in Annex IV of the END and should be reviewed every 5 years.

2.1.2 *Action plans, quiet areas and public participation*

Based upon noise mapping results, Member States must prepare action plans containing measures addressing noise issues and their effects for major roads, railways, airports and agglomerations. According to Article 8.1(b), the plans should also aim to protect quiet areas against an increase in noise.

Map 2.1 Urban areas with more than 100 000 inhabitants in EEA member countries



The action plans must meet the minimum requirements laid down in Annex V of the END, relating, inter alia, to designation of competent authorities, indication of any limit values in place, noise-reduction measures already in place and projects in preparation, actions to be taken in the following 5 years, long-term strategies and financial information. However, it is important to note that the END does not impose any limit values or specific measures that need to be included in the action plans — those measures are left at the discretion of competent national authorities. The END also requires that the public shall have the opportunity to comment on proposals for action plans and the possibility to participate in the elaboration and reviewing of the action plans (Article 8).

2.1.3 *Data collection and reporting*

The reporting obligations set out under the END are contained in a number of provisions. These have been consolidated into the Electronic Noise Data Reporting Mechanism (ENDRM) (EEA, 2012).

Member States are further obliged to provide the Commission with information from their strategic noise maps, summaries of the action plan details and noise control programmes at regular intervals, as well as to update the Commission on competent bodies, noise limit values and designated roads, railways, airports and agglomerations. The ENDRM categorises these obligations into a series of Data Flows, which are summarised in Table 2.1.

2.2 Completeness of the END data set

The completeness of the information reported under the END can be assessed in general terms by relating DF1_5 of the ENDRM to DF4_8 of the ENDRM. In other words, an assessment of whether the reported noise maps correspond to the source data reported almost 2 years previously.

Map 2.2 Major airports with more than 50 000 movements/year in EEA member countries

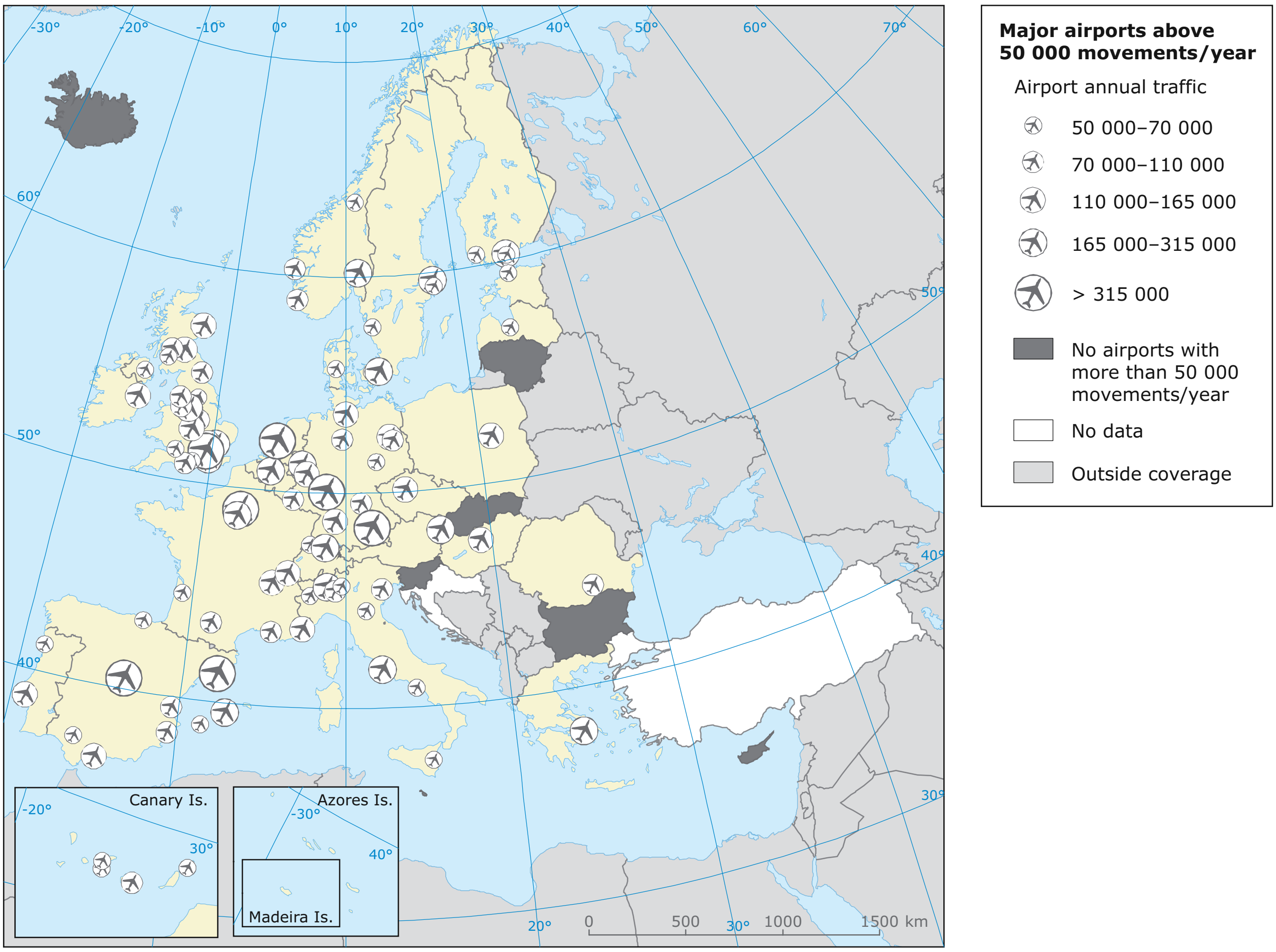


Table 2.1 ENDRM data flows

Data flow	Summary description of information to be reported	Legally binding deadline	Updates by MSs	END provision
DF0	Definition of reporting structure	-	-	-
DF1_DF5	Major roads, major railways, major airports and agglomerations designated by the MS	First legally binding deadline: 30 June 2005 (1st implementation step) Second legally binding deadline: 31 December 2008 (2nd implementation step)	Mandatory every 5 years	Art. 7-1 Art. 7-2 Art. 7-5
DF2	Competent bodies for strategic noise maps, action plans and data collection	18 July 2005	Possible at any time	Art. 4-2
DF3	Noise limit values in force or planned and associated information	18 July 2005	Possible at any time	Art. 5-4
DF4_8	Strategic noise maps-related data as listed in Annex VI for major roads, railways, airports and agglomerations	First legally binding deadline: 30 December 2007 (1st implementation step) Second legally binding deadline: 30 December 2012 (2nd implementation step)	Mandatory every 5 years	Art. 7-1 Art. 7-2 Art. 7-5 Art. 10-2 Annex VI
DF6_9	Noise-control programmes that have been carried out in the past and noise measures in place	First legally binding deadline: 18 January 2009 (1st implementation step) Second legally binding deadline: 18 January 2014 (2nd implementation step)	No updates	Art. 10-2 Annex VI 1.3 & 2.3
DF7_10	Action plans-related data as listed in Annex VI for major roads, railways, airports and agglomerations, and any criteria used in drawing up action plans	First legally binding deadline: 18 January 2009 (1st implementation step) Second legally binding deadline: 18 January 2014 (2nd implementation step)	Mandatory every 5 years	Art. 8-1 Art. 8-2 Art. 8-5 Art. 10-2 Art. 10-5 Annex VI Art. 8-3

Source: EEA, 2012.

On this basis, the data set on population exposure to major noise sources in Europe can be considered to be much more complete for 2007 than it is for 2012. A summary of this completeness analysis, for each noise source, can be found in Tables 2.2, 2.3, 2.4 and 2.5.

Table 2.2 Noise database: major roads' completeness

Reporting year	Noise sources ([a])			Strategic noise maps ([b])	Completeness (at country level)
	Length of major roads	Number of countries reporting data	Number of countries expected to report data	Number of countries reporting data	
2007	73 038	29	32	29	90 %
2012	180 767 ([c])	30	33	21	63 %

Note: ([a]) Refers to agglomerations, major roads, major railways and major airports designated by the END where strategic noise maps and action plans should be developed. This information is made available to the European Commission 2 years before the submission of the strategic noise maps (Article 7).

([b]) Refers to information on noise exposure and on noise contour maps to be submitted to the European Commission in those areas (agglomerations, major roads, major railways and major airports) designated by the END (Article 7, Annex VI).

([c]) Denmark, France, Germany, Greece, Iceland, Italy, Luxembourg, the Netherlands: data on length of major road infrastructure not complete.

Table 2.3 Noise database: major railways' completeness

Reporting year	Noise sources ([a])			Strategic noise maps ([b])	Completeness (at country level)
	Length of major railways	Number of countries reporting data	Number of countries expected to report data	Number of countries reporting data	
2007	11 721	21	24	21	87 %
2012	40 066 ([c])	26	28	17	60 %

Note: ([a]) Refers to agglomerations, major roads, major railways and major airports designated by the END where strategic noise maps and action plans should be developed. This information is made available to the European Commission 2 years before the submission of the strategic noise maps (Art. 7).

([b]) Refers to information on noise exposure and on noise contour maps to be submitted to the European Commission in those areas (agglomerations, major roads, major railways and major airports) designated by the END (Art. 7, Annex VI).

([c]) Denmark, France, Germany, Greece, Italy, Luxembourg, the Netherlands: Data on length of major railways infrastructure not complete.

Table 2.4 Noise database: major airports' completeness

Reporting year	Noise sources ([a])	Strategic noise maps ([b])	Completeness
	Number of major airports	Number of major airports	
2007	78	74	95 %
2012	91	56	62 %

Note: ([a]) Refers to agglomerations, major roads, major railways and major airports designated by the END where strategic noise maps and action plans should be developed. This information is made available to the European Commission 2 years before the submission of the strategic noise maps (Art. 7).

([b]) Refers to information on noise exposure and on noise contour maps to be submitted to the European Commission in those areas (agglomerations, major roads, major railways and major airports) designated by the END (Art. 7, Annex VI).

Table 2.5 Noise database: agglomerations' completeness

Reporting year	Noise sources ([a])	Strategic noise maps ([b])				Completeness
	Number of agglomerations	Source	Number of agglomerations to be reported	Number of agglomerations reported	Number of agglomerations not reported	
2007	164	Road	163 ([c])	154	9	94 %
		Rail	161	145	16	90 %
		Aircraft	138	121	17	87 %
		Industry	159	137	22	86 %
2012	471	Road	471	294	177	62 %
		Rail	460	270	190	57 %
		Aircraft	381	167	214	44 %
		Industry	463	260	203	56 %

Note: ([a]) Refers to agglomerations, major roads, major railways and major airports designated by the END where strategic noise maps and action plans should be developed. This information is made available to the European Commission 2 years before the submission of the strategic noise maps (Art. 7).

([b]) Refers to information on noise exposure and on noise contour maps to be submitted to the European Commission in those areas (agglomerations, major roads, major railways and major airports) designated by the END (Art. 7, Annex VI).

([c]) One agglomeration that was included in the database according to a Member State's delivery, but declared afterwards as not being anymore an agglomeration for the first reporting period.

2.3 Gap-filling

The second round of noise mapping data can presently only be considered as approximately 44 % complete depending on source. In order to ensure as full an assessment of environmental noise in Europe as possible, the EEA undertook a gap-filling analysis.

This analysis used the data set of all noise mapping data reported up to 28 August 2013, and applied a series of methods to attempt to bring the data set up to the expected level of completeness for noise maps due to have been reported by 30 December 2012.

Different extrapolation factors were applied according to noise source, and applied to each remaining noise source both within agglomerations and for major sources outside agglomerations. A report describing the methodologies employed is available (Extrium, 2013).

An example of the extrapolation methodology as applied to agglomeration road data are provided in Annex 2.

The 'gap-filled' data set was applied to the European noise exposure assessment described in Chapter 3. Where analysis looks at information reported for individual cities and countries, only the reported information (i.e. not gap-filled) data was used. The health impact assessment provided in Chapter 4 similarly relies upon the less complete reported information only, implying that the findings are underestimated, and potentially significantly so.

Box 2.2 Common noise assessment methods for Europe: CNOSSOS-EU

As noted previously, noise mapping data contain a number of inconsistencies as a result of different assessment approaches being applied by Member States (Licitra and Ascari, 2013; Kephalopoulos and Paviotti, 2013). In the context of the END, the European Commission has prepared Common NOise aSSessment methOdS (CNOSSOS-EU) for road, railway, aircraft and industrial noise in order to improve the reliability and the comparability of results across EU Member States (JRC, 2014). However, until this common approach is developed, Member States are allowed to use interim methods, based on national computation methods.

National methods differ both in noise source description and propagation part — e.g. with respect to the handling of meteorological conditions and noise absorption by the ground. It has been pointed out that for road traffic noise, results of calculation methods show differences up to 5–10 dB in single elements on the propagation part of calculations (Kephalopoulos and Paviotti, 2013). The assignment of noise levels and population to the buildings and the criteria for the delineation of agglomerations can also have an influence on the reported results.

Fully implemented, CNOSSOS-EU will allow for a significantly improved coherent, transparent, optimised and reliable reporting of information for strategic noise mapping and action planning in relation to the data requirements, their quality and availability, and, in terms of flexibility, to adapt the national databases of input values. Application of the CNOSSOS methodology will only be mandatory after the next (2017) reporting round — i.e. for information to be reported in 2022.

3 Exposure to environmental noise in Europe

3.1 Overall European picture

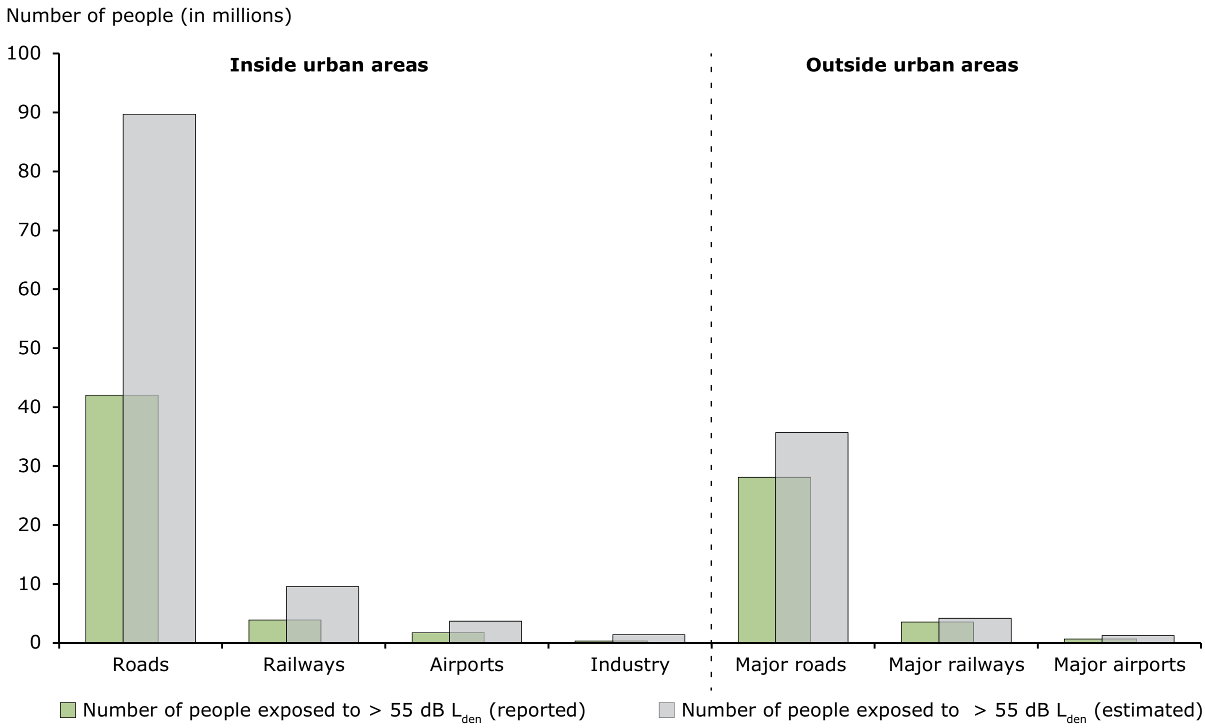
What we learn from two rounds of noise mapping assessments implemented in accordance with the END is that road traffic noise, both inside and outside urban areas ([2]), is the most dominant source affecting human exposure above the action levels defined by the END.

The impacts and affects resulting from this noise exposure vary depending on which levels the population is exposed to. Estimations, based on calculated figures complementing current reported data on noise exposure to estimate the overall number of people exposed, show that more than 125 million people could actually be exposed to road traffic noise above 55 dB L_{den} ([3]), including more than 37 million exposed to noise levels above 65 dB L_{den}.

Figure 3.1 indicates the potential extent of missing information for the overall implementation of the END based on estimates, as about 45 % for road traffic exposure inside urban areas and 78 % for major road traffic exposure outside urban areas is actually delivered (as a percentage of the estimated exposure).

Differences between reported and estimated exposure figures show that the 2012 data set is

Figure 3.1 Number of people exposed to noise in Europe > 55 dB L_{den} in EEA member countries (2012): reported and estimated data



([2]) Urban areas are described in the END as 'agglomerations', meaning the part of the territory, delimited by the Member State, having a population in excess of 100 000 persons and a population density such that the Member State considers it to be an urbanised area. Noise mapping outside urban areas is restricted to major infrastructure.

([3]) 55 dB L_{den} is the EU threshold for excess exposure, indicating a weighted average during the day, evening and night.

far from complete for the other END sources of noise (Figure 3.1). Reported data from highest to lowest values of exposure show rail traffic noise (nearly 8 million people exposed above 55 dB L_{den}), aircraft noise (below 3 million people exposed above 55 dB L_{den}) and industrial noise — within urban areas only (300 000 people exposed above 55 dB L_{den}).

The END requires the provision of exposure data in 5 decibel bands (55–59 dB L_{den}, 60–64 dB L_{den}, 65–69 dB L_{den}, 70–74 dB L_{den}, > 75 dB L_{den}). Health risks can increase with higher levels of exposure, and noise-abatement measures to be implemented may also differ depending on the source and on the specific noise-level band being addressed.

Figure 3.2 shows the exposure data as reported by EEA member countries for noise bands above 55 dB L_{den}. The highest percentage of people reported in 2012 ([4]) are exposed to the lower decibel bands for all noise sources.

The noise source with the highest percentage of people exposed between 55–59 dB and 60–64 dB L_{den} is aircraft noise, with values of 92 % and 98 % people exposed inside and outside urban areas, respectively.

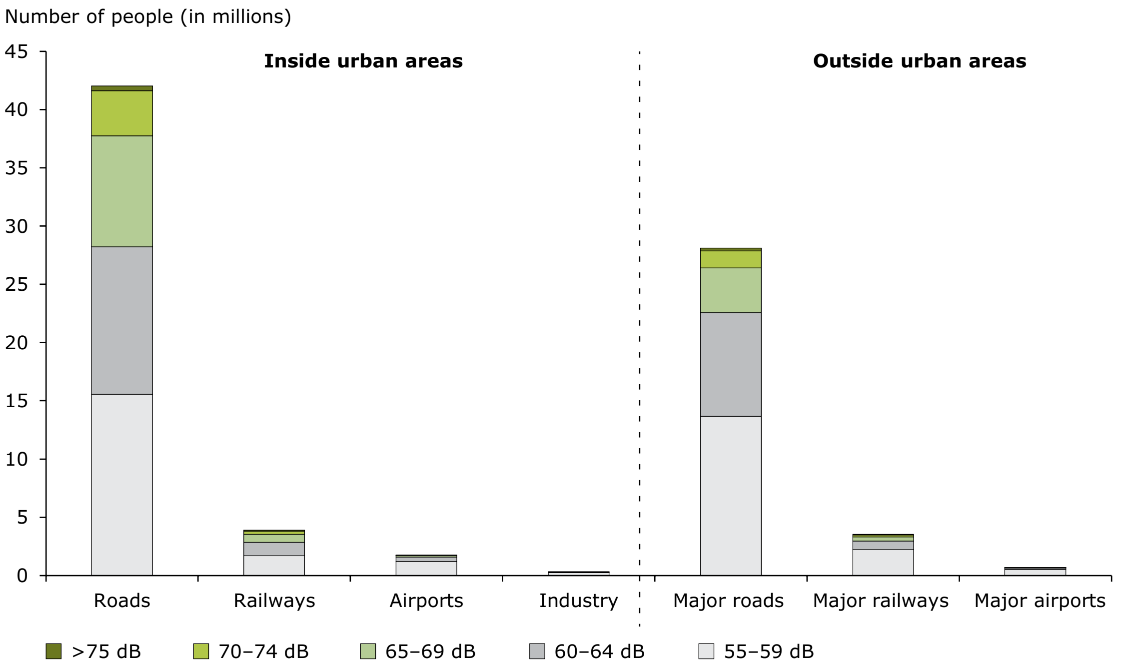
On the other hand, road traffic noise presents a more balanced distribution among the population exposed to the five noise bands, both inside and outside urban areas.

3.2 Road transport noise

Road traffic is the most widespread noise source in Europe and the one causing the most number of people to be exposed above the END action levels for L_{den} and L_{night}. This is true at European scale, at country scale, and both inside and outside the major urban agglomerations.

Road traffic noise is caused by the combination of rolling noise and propulsion noise. Rolling noise is the interaction between the vehicle tyre and the road surface, and it is estimated that above a speed of 40 km per hour for most of the cars, and above 70 km per hour for trucks, it constitutes the main source of road traffic noise (Van Blokland and Peeters, 2009). Below those speeds, the main source of road traffic noise is the propulsion noise, comprising the engine itself, the exhaust systems and transmission intake. The vehicles that contribute more to road traffic noise are passenger cars and lorries, and less so buses and motorcycles (T&E, 2008).

Figure 3.2 Number of people exposed to noise per decibel band in Europe L_{den} (2012)



([4]) Data reported by EEA member countries until 28 August 2013.

Box 3.3 Population exposure to major noise sources in 2007

In 2007, the first reporting round of noise exposure to major sources in Europe was required under the obligations of the END. Data that was required included exposure information for urban agglomerations with a population of more than 250 000 inhabitants, major roads with more than 6 million vehicles per year, major railways with more than 60 000 trains per year, and major airports with more than 50 000 air traffic movements per year. In agglomerations, assessments were to have been conducted for roads, railways, airports and industrial noise, which included sea ports.

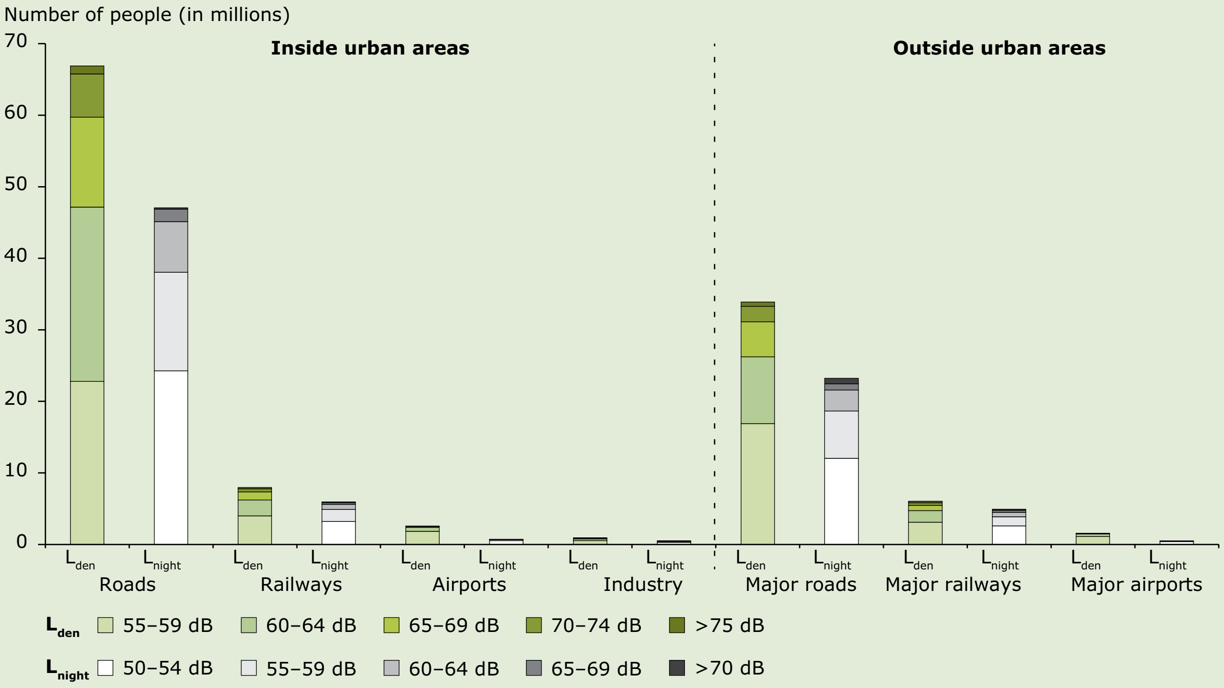
The reported data are expressed in two exposure indicators (L_{den} and L_{night}) divided into five classes of noise exposure:

- for L_{den}: exposure classes of 5 dB from 55 dB up to over 75 dB;
- for L_{night}: exposure classes of 5 dB classes from 50 dB up to over 70 dB.

The 2007 data set on population exposure to major noise sources in Europe is judged to be largely complete in terms of data submitted by EEA member countries.

Noise from road traffic was clearly the source for which the largest number of people was exposed to at European level. More than 100 million people (living inside and outside urban areas) were exposed to road traffic noise above 55 dB L_{den} (Figure 3.3). The ENDRM accommodates the reporting of noise mapping exposure assessments in line with the NNGL level of 40 dB, but to date only a few EEA member countries have responded with these data.

Figure 3.3 Number of people exposed to noise in Europe, L_{den} and L_{night} (2007)



Noise exposure from other sources (inside and outside urban areas), although lower values than that from road traffic exposure, was also significant:

- more than 14 million people were exposed to more than 55 dB L_{den} due to railway noise;
- more than 4 million people were exposed to more than 55 dB L_{den} due to aircraft noise;
- industrial noise inside urban areas showed the lowest percentage of people exposed in Europe, with less than 1 million people exposed to more than 55 dB L_{den}.

Between 2007 and 2012, exposure to noise in selected urban agglomerations remained broadly constant according to L_{den} and L_{night} indicators (a 2 % decrease of L_{den} > 55 and a 3 % reduction for L_{night} > 50 dB). The comparison is based upon a subset of 44 selected agglomerations in 10 Member States reported by countries for these 2 years, and for which data are considered comparable.

Box 3.4 Noise pollution as a spatial concept

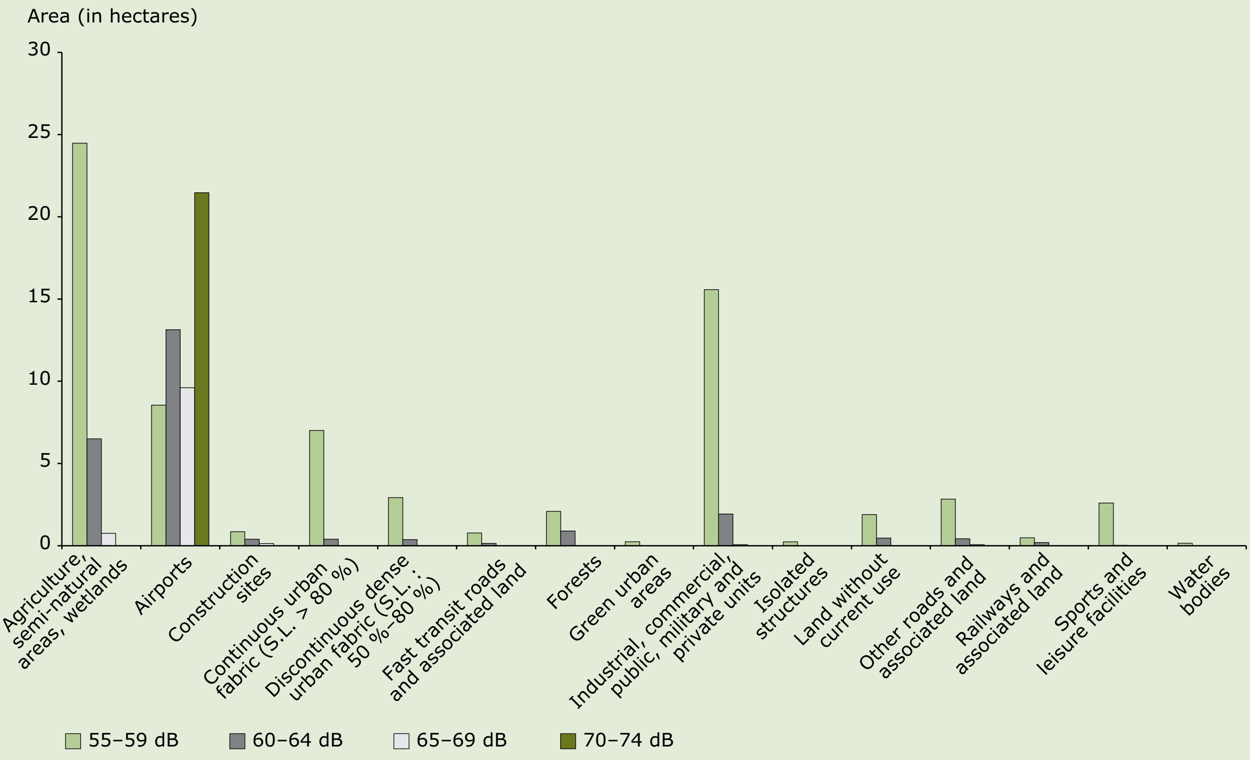
Noise pollution is a spatially dependent phenomenon (Cueto and Licitra, 2013). Geographic information systems can help in the analysis of this pollutant and assist the understanding of how noise affects an ecosystem and its population.

The location of noise sources as well as the analysis of the area exposed to different levels of noise can give an overall picture of where the major problems in the European territory are occurring. The 55 dB and 65 dB contours are those required to be shown graphically on noise maps sent to the European Commission for major transport networks of roads and railways, as well as for major airports.

By analysing the noise contour maps being provided, it is possible to identify where potential conflicts are occurring (e.g. high densely populated areas exposed to high levels of noise) and if more than one noise source is affecting the same area (e.g. major road and major railway running in parallel and affecting the same village), among others.

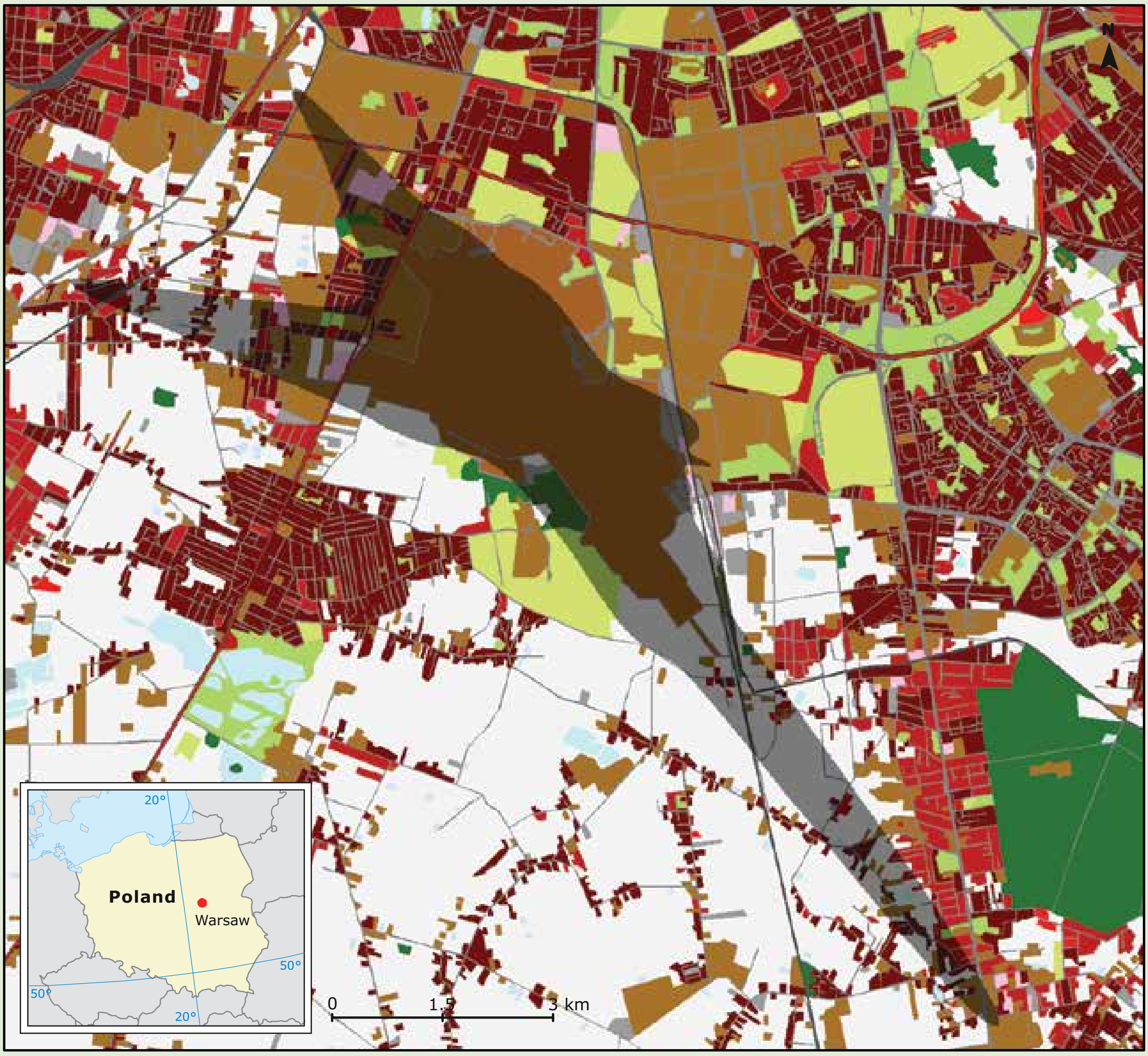
By overlaying the 55 dB and 65 dB noise contours with a land cover data set, the land cover and land use areas most affected by noise can be identified, enabling the comparison among countries, regions and even at major source level (in this case, at major airport level). Areas of high noise exposure can also be identified at local scale, where the location and location conditions of the noise source determine the number of people exposed. This is particularly true in the case of major airports, where location of settlements and residential areas nearby a major airport and its footprint are crucial regarding the number of people exposed and the derived health problems, e.g. Warsaw Chopin Airport: analysis at major airport level (Figure 3.4 and Map 3.1). This analysis enables making an objective assessment of the noise impact caused by the major airport in the surrounding area, allowing a more in-depth analysis on schools, hospitals and other noise-sensitive buildings and areas if desired.

Figure 3.4 Land cover classes affected by noise contours of Warsaw Chopin Airport



Box 3.4 Noise pollution as a spatial concept (cont.)

Map 3.1 Land cover classes affected by noise contours of Warsaw Chopin Airport



Land cover classes affected by noise contours of Warsaw Chopin Airport

Area of L_{den} > 55 dB

Transport
- Railways
- Main roads
- Secondary roads
- Port areas
- Airport

Urban fabric
- Continuous urban fabric (S.L > 80 %)
- Discontinuous dense urban fabric (S.L 50–80 %)
- Discontinuous medium density urban fabric (S.L 30–50 %)
- Discontinuous low dentsity urban fabric (S.L 10–30 %)
- Discontinuous very low urban fabric (S.L < 10 %)

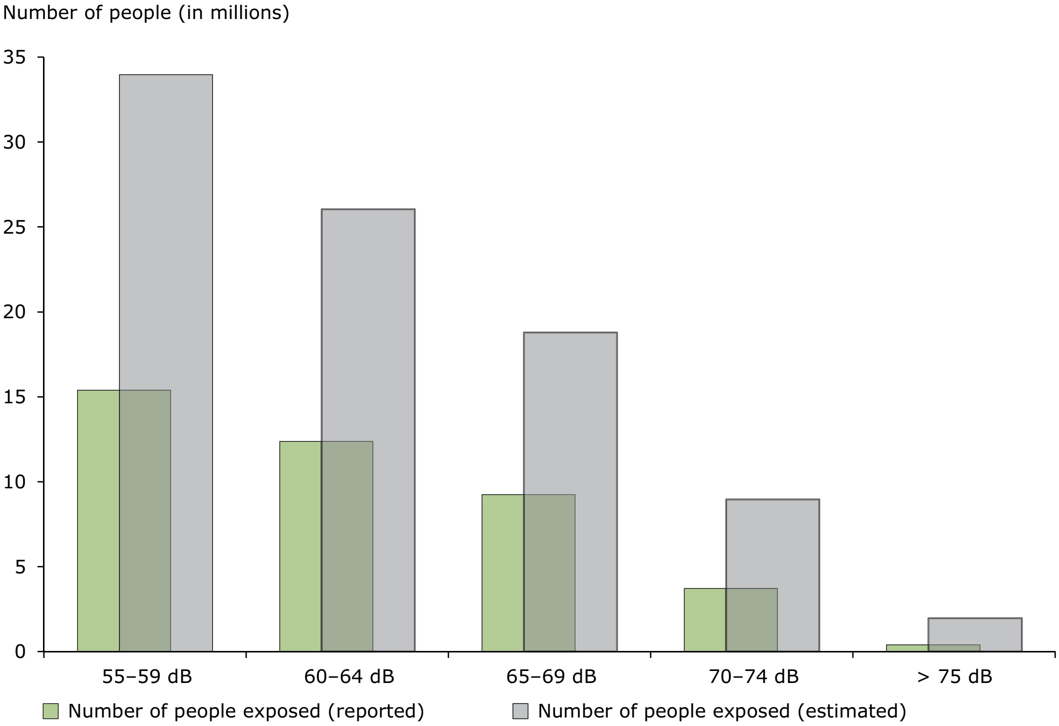
Urban and industrial areas
- Mineral extraction and dump sites
- Industrial, commercial, public, military and private units
- Construction sites
- Isolated structures
- Land without current use

Agricultural, semi-natural areas and water
- Water bodies
- Agricultural, semi-natural areas, wetlands

Recreational areas
- Sports and leisure facilities
- Green urban areas
- Forests

Sources: NOISE database, August 2013; Urban Atlas, 2006.

Figure 3.5 Number of people exposed to road traffic noise inside urban areas with more than 100 000 inhabitants, L_{den}, EEA member countries (2012): reported and estimated data



Patterns of increased urbanisation are found all across Europe and are more increasingly affecting once recently rural regions. This growth is mainly driven by economic and demographic factors, housing preferences and social aspects, transportation and regulatory frameworks. 'Artificial land cover increased by 3.4 % in Europe between 2000 and 2006 — by far the largest proportional increase in all land use categories. Although artificial cover accounts for just 4 % of the EU's land area, the fact that it is dispersed means that more than a quarter of EU territory is directly affected by urban land use' (EEA, 2014a). Implications of urban area extensions, especially low density and scattered urban sprawl areas, can have benefits on the one hand (people have more space to live, gardens, etc.) and on the other hand can create negative impacts such as increase in energy demand, human health problems, social and economic division, and reduction of natural resources.

Considering then that transport networks are an important driver at the regional and national levels — as urban areas grow along communication axes — and the guarantee they offer concerning mobility and access to goods, it is important to ensure an effective road transport policy requiring a concerted approach that should balance the need to reduce road-related sound emission without affecting mobility and its associated socio-economic benefits (ERF, 2004).

Based on this situation, it is clear that with this trend on urban areas' growing, population density decreases per built-up area on European average,

Photo: © Colin Nugent

but at the same time an increase of transport demand is occurring, deriving a set of pressures on the environment, such as the unsustainable use of natural resources, greenhouse gases, and air pollutant and noise emissions (EEA, 2013).

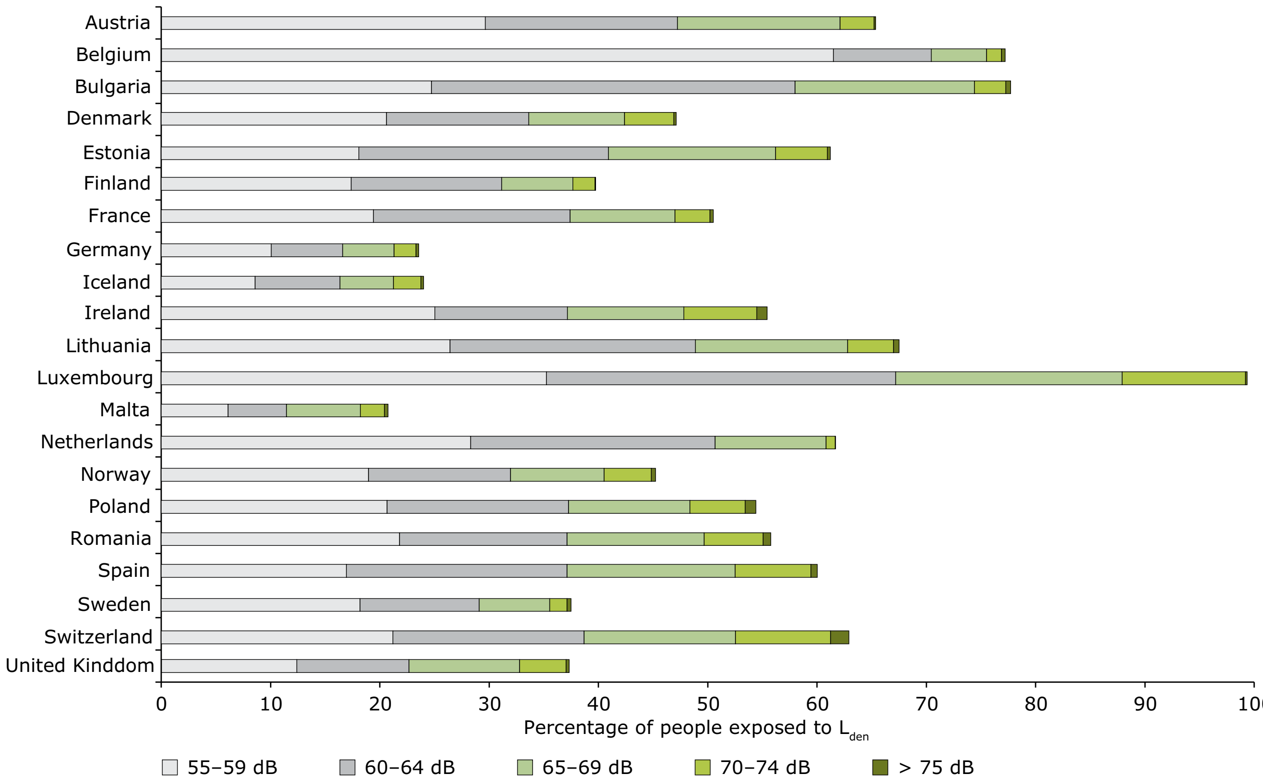
Based upon current data, more than 41 million people are reported to be exposed above 55 dB L_{den} due to road traffic noise inside urban areas. Estimations show that the overall number of people exposed to road noise increases by more than twice the current figure, reaching nearly 90 million people exposed to road traffic noise inside urban areas in Europe. Adding to this figure, the estimated number of people exposed to major roads outside urban areas, the overall figure is around 24 % of the total European population ([5]) i.e around 125 million people, are likely to be exposed to road traffic noise according to the END (Figure 3.1) ([6]).

A wide range of variation can be identified among countries for the number of people exposed to road traffic noise inside urban areas, influenced greatly by factors such as the number of urban areas per country or the total number of inhabitants per urban area. Correlation between the total number of inhabitants of an urban area and the number of people exposed to road traffic noise is very high.

At country level, Austria, Estonia, Ireland, Lithuania, the Netherlands, Poland, Romania, Spain and Switzerland reported more than 50 % of inhabitants exposed to road noise above 55 dB L_{den} in urban areas with more than 100 000 inhabitants.

Belgium, Bulgaria and Luxembourg reported more than 75 % of inhabitants exposed to road traffic noise, though much data had still not been reported at the time of writing (see Figure 3.6).

Figure 3.6 Percentage of population exposed to road noise, L_{den}, in 294 urban areas, EEA member countries (2012)



Note: France: Only reported agglomerations from 100 000 to 250 000 inhabitants in 2012.

Liechtenstein: Data not applicable (there is no agglomeration above 100 000 inhabitants in the country).

Cyprus, Czech Republic, Greece, Hungary, Italy, Latvia, Portugal, Slovenia, Slovakia: Data not provided.

([5]) Total population in Europe considering the 33 EEA member countries (Eurostat, 2010).

([6]) Exposure in urban areas with less than 100 000 inhabitants or along transport networks with less traffic are not considered under the END scope and, therefore, not required to be mapped.

The highest percentage of people exposed to road traffic noise inside urban areas are exposed to the two lowest noise bands mapped: 55–59 dB and 60–64 dB L_{den}. When considering urban areas with more than 250 000 inhabitants solely, the distribution of exposed people among L_{den} noise bands is subtly different. A potential increase in the number of people exposed to higher decibel bands seems to occur in medium-size urban areas (from 100 000 to 250 000 inhabitants).

For agglomerations, there can also be a wide difference when comparing urban areas from the same country. Percentages displayed in Figure 3.7 are based on data exposure reported by the different EEA member countries. General observation may only be made for those cases where the data could be considered complete or nearly complete. This is true for Germany, which, for the moment, is a country where the differences between individual agglomerations are less pronounced. On the other hand, the United Kingdom data show an unexpected profile, which may illustrate a different methodological approach to noise mapping that could adversely affect the analysis at a European level.

The net change at the European level of people exposed to road traffic noise inside urban areas from 2007 to 2012 shows a decrease in the number of people exposed. This analysis takes into account 71 urban areas with more 250 000 inhabitants that have reported information both in 2007 and 2012 (the incompleteness of the whole data set is an important factor to take into consideration when analysing trends, as they may vary when the complete data set is available). The decrease in the number of people exposed is highly influenced by the results from the United Kingdom (see Figure 3.8 to analyse differences between countries). Nevertheless, the United Kingdom can be considered a particular case compared with the rest of countries, where it can be observed that all noise bands increase or the exposure to the lowest bands is increasing while exposure to the highest bands is decreasing (e.g. Ireland, Poland and Spain).

The situation for major road traffic exposure outside agglomeration is quite similar to the analysis of road traffic exposure inside urban areas. It is clearly the noise source with the highest number of exposed people reported in the European territory. The total number of people exposed to road traffic noise could be expected to correlate with the kilometres of major roads reported in each country (Figure 3.9).

In Europe, more than 28 million people are reported to be exposed above 55 dB L_{den} due to major road traffic noise ([7]) outside urban areas. With the estimations done to complement current reported data with still missing data, this figure is expected to increase up to more than 35 million people exposed to major road traffic noise.

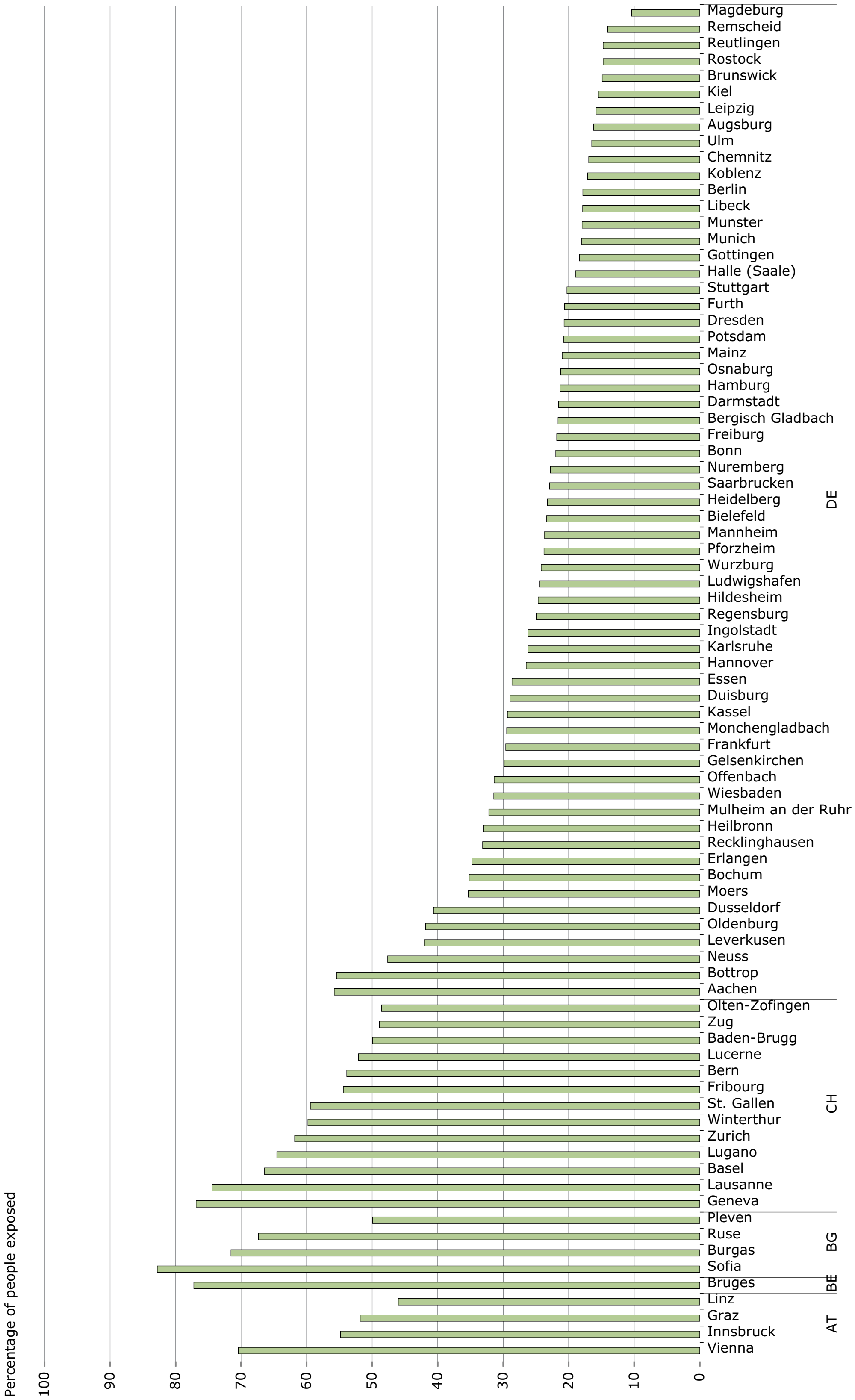
The majority of people are exposed to the lower noise bands, as in the case of road traffic noise exposure inside urban areas (Figure 3.10). The distribution of the people exposed among the different noise bands is a bit different when considering all major roads above 3 million vehicles, and not only a subset of major roads with more than 6 million vehicles. Broadly, it could be observed at country level that there is an overall increase of the portion of people exposed to higher bands (people exposed from 65–69 dB and from 70–74 dB L_{den}) and at the same time, a reduction on the number of people exposed to values above 75 dB in some countries.

Nevertheless, it is clear that lack of data (e.g. countries not yet delivering information and countries delivering incomplete information) is influencing these observations, which may change when the complete information is available.

People exposed to road traffic noise including urban areas is, on average, three times higher than solely considering road traffic exposure outside urban areas, if analysed over the total population of the country (Figure 3.11). From the total amount of people reported as exposed to road traffic noise, the percentage of people exposed who are living inside agglomerations ranges from 50 % in cases such as Bulgaria, Iceland, Liechtenstein, Poland and Sweden, up to 92 % for Lithuania or the Netherlands (Estonia reaches 100 % because exposure due to road traffic noise outside agglomerations has not been provided, and therefore it has been excluded from these results).

([7]) Major roads with more than 3 million vehicles/year.

Figure 3.7a Percentage of people exposed to road traffic noise inside urban areas with 100 000 inhabitants > 55 dB L_{den} (2012)



Note: France: Only reported agglomerations from 100 000 to 250 000 inhabitants in 2012.
Liechtenstein: Data not applicable (there is no agglomeration above 100 000 inhabitants in the country).
Cyprus, Czech Republic, Greece, Hungary, Italy, Latvia, Portugal, Slovenia, Slovakia: Data not provided.

Figure 3.7b Percentage of people exposed to road traffic noise inside urban areas with 100 000 inhabitants > 55 dB L_{den} (2012)

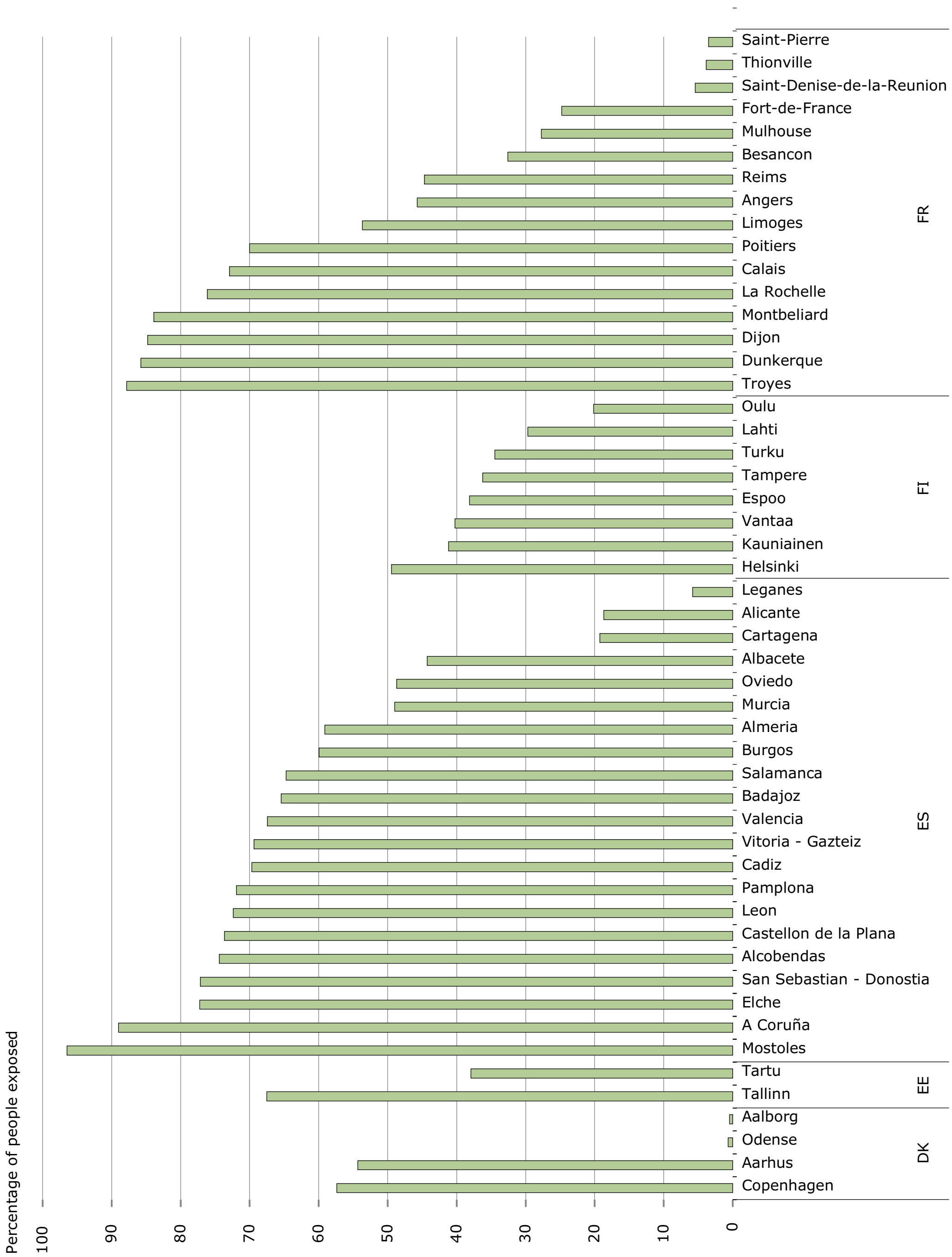


Figure 3.7c Percentage of people exposed to road traffic noise inside urban areas with 100 000 inhabitants > 55 dB L_{den} (2012)

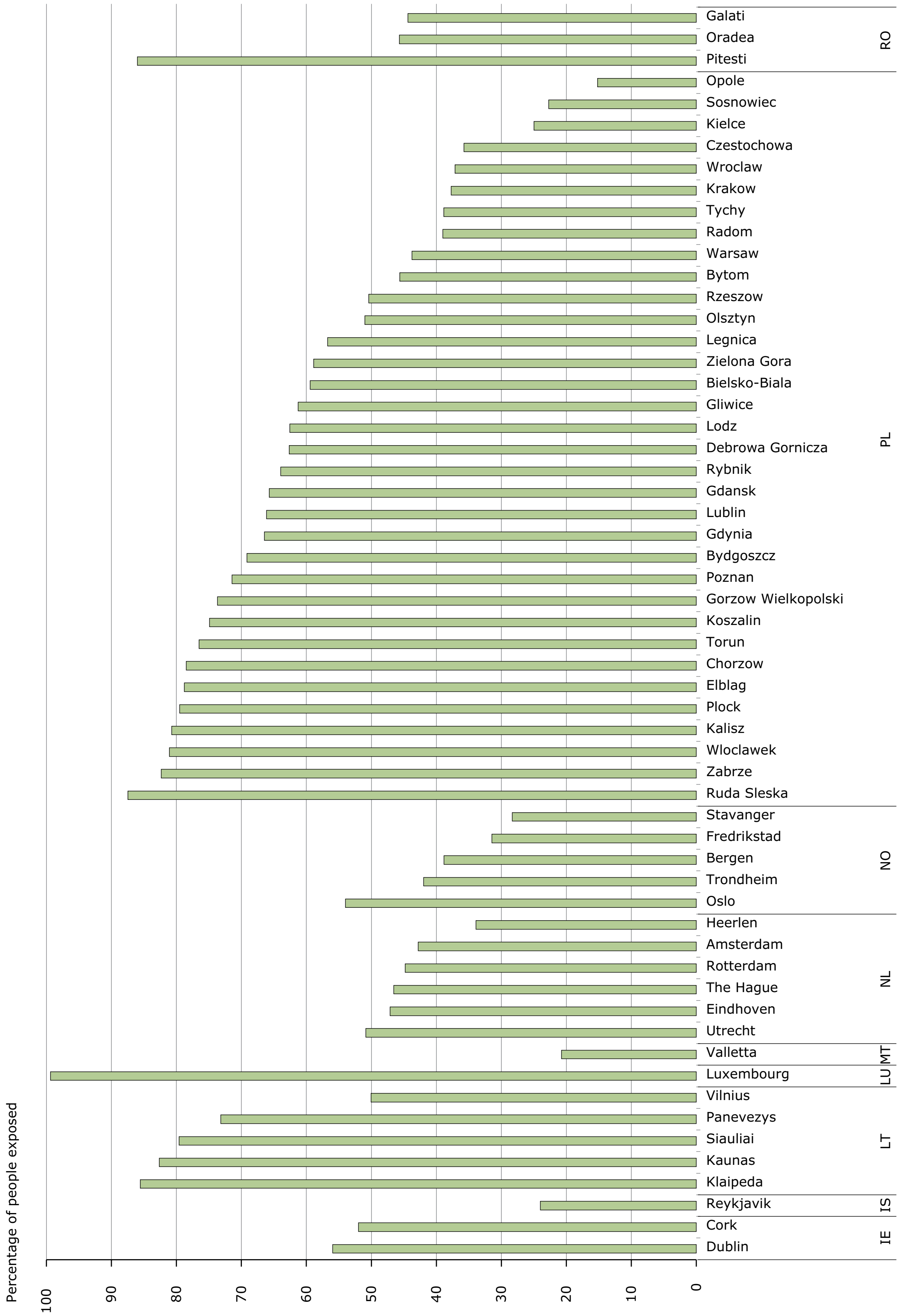
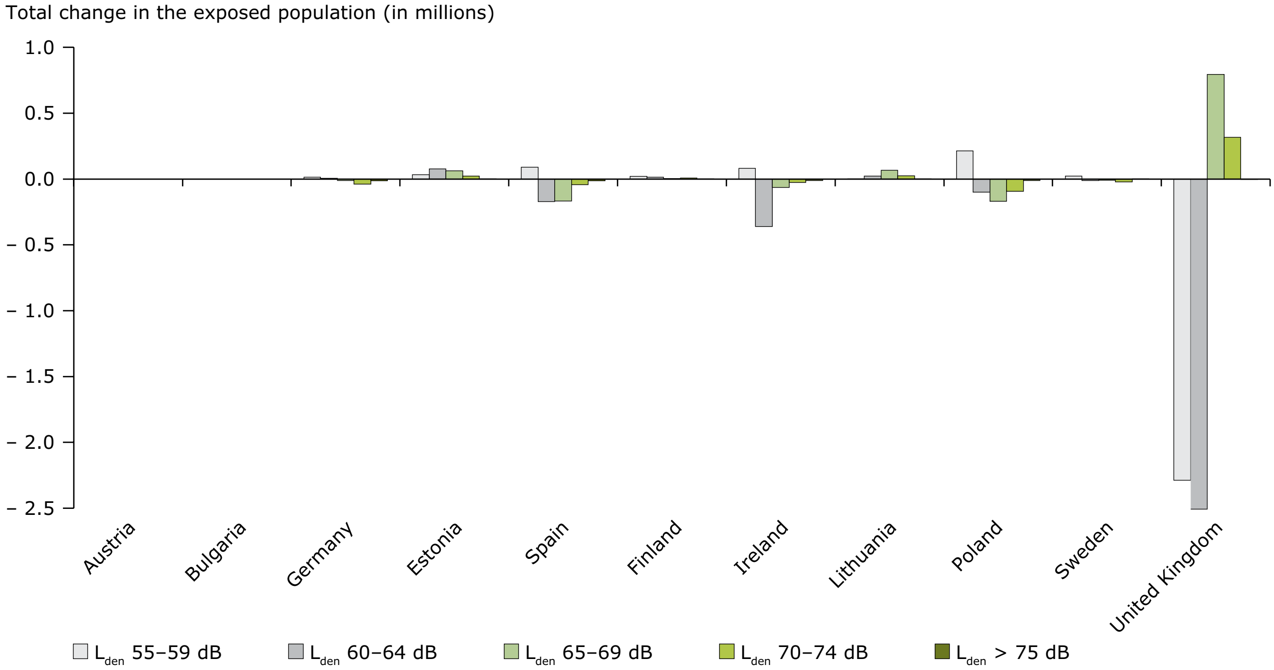


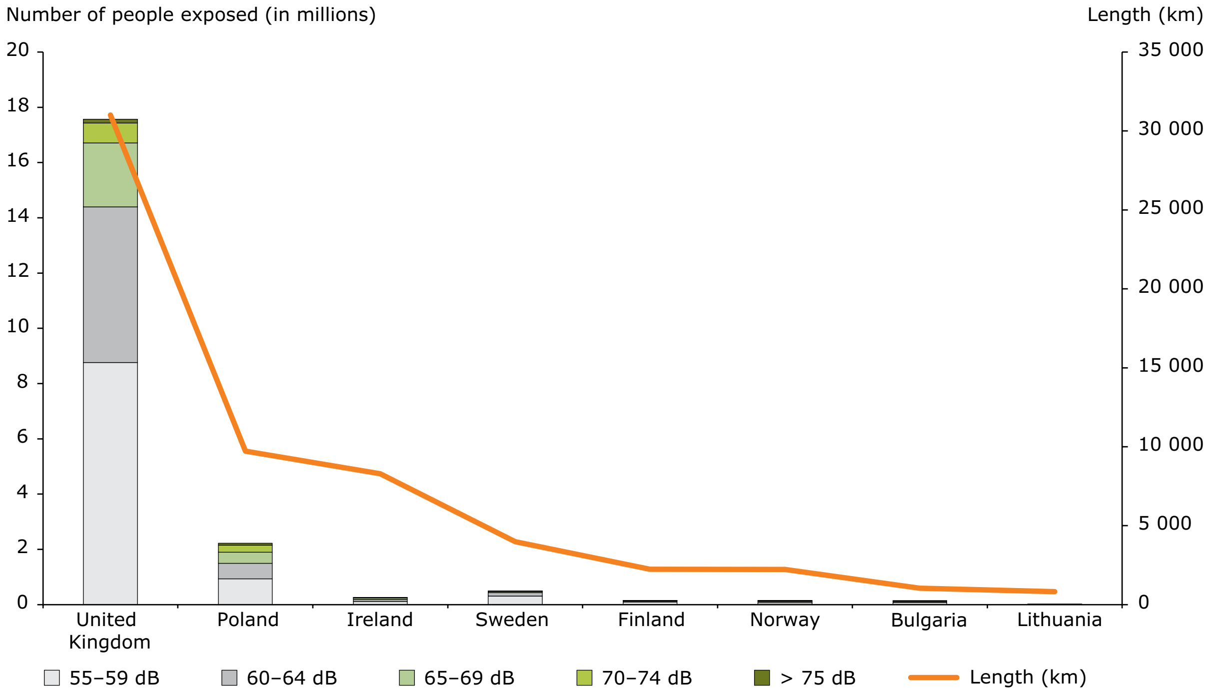
Figure 3.7d Percentage of people exposed to road traffic noise inside urban areas with 100 000 inhabitants > 55 dB L_{den} (2012)

Figure 3.8 Total change of people exposed to road noise inside urban areas, L_{den}, at country level (2007–2012)



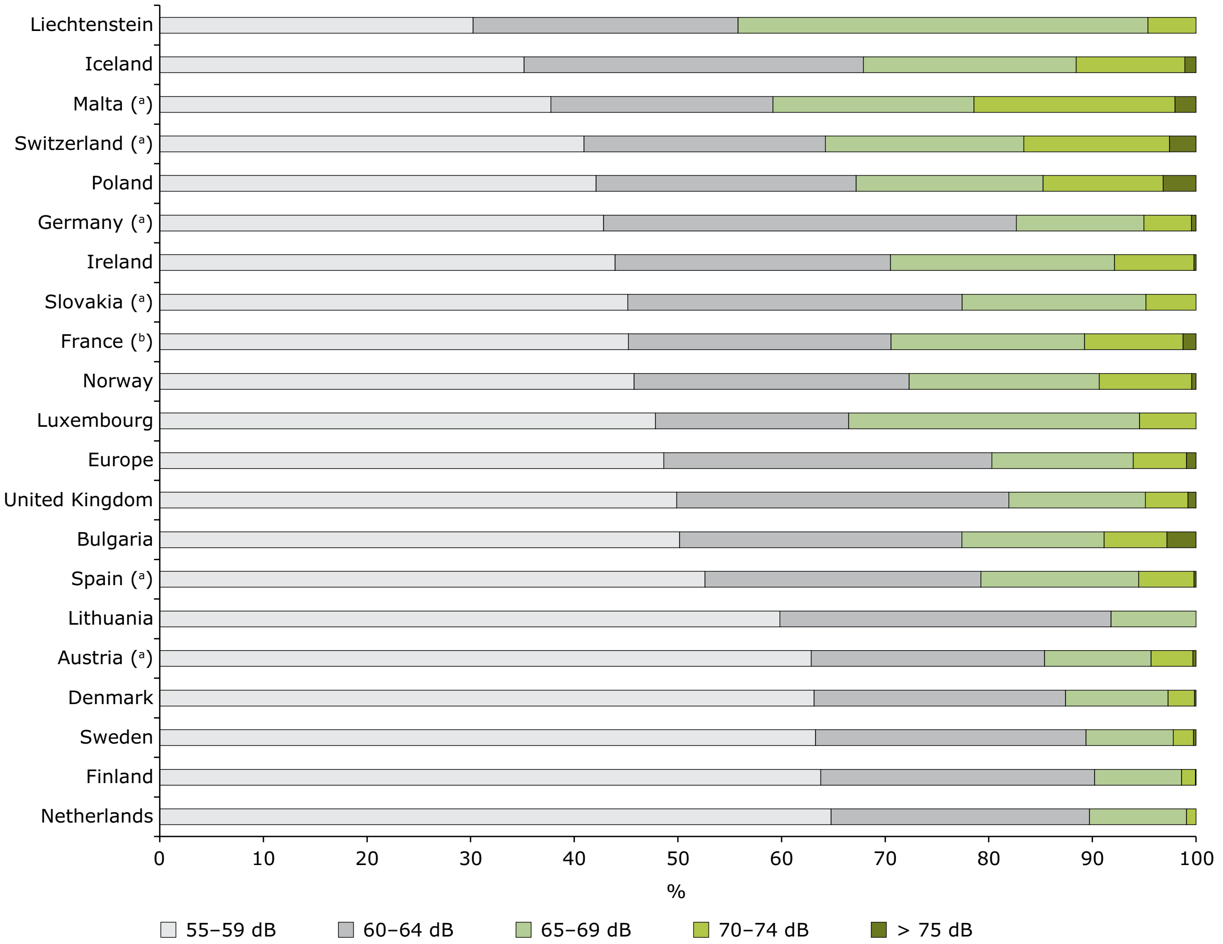
Note: X axis has been cut at − 2.5 million people for visualisation purposes. Noise band L_{den} 60–64 dB for the United Kingdom reaches 6 067 300 people exposed.

Figure 3.9 Number of people exposed to major roads > 3 million vehicles/year outside urban areas, L_{den}, versus reported kilometres of major roads outside urban areas (2012)



Note: Estonia: Provision of information on exposure to major roads including agglomerations solely.
Austria, France, Germany, Malta, Slovakia, Spain, Switzerland: Exposure information under review.
Denmark, Iceland, Liechtenstein, Luxembourg, the Netherlands: Length data incomplete or information concerning major roads above 3 million vehicles/year not reported.
Belgium, Croatia, Cyprus, Czech Republic, Greece, Hungary, Italy, Latvia, Portugal, Romania, Slovenia, Turkey: Data not provided.

Figure 3.10 Distribution of population exposed to major roads > 3 million vehicles/year outside agglomerations, L_{den} (2012)



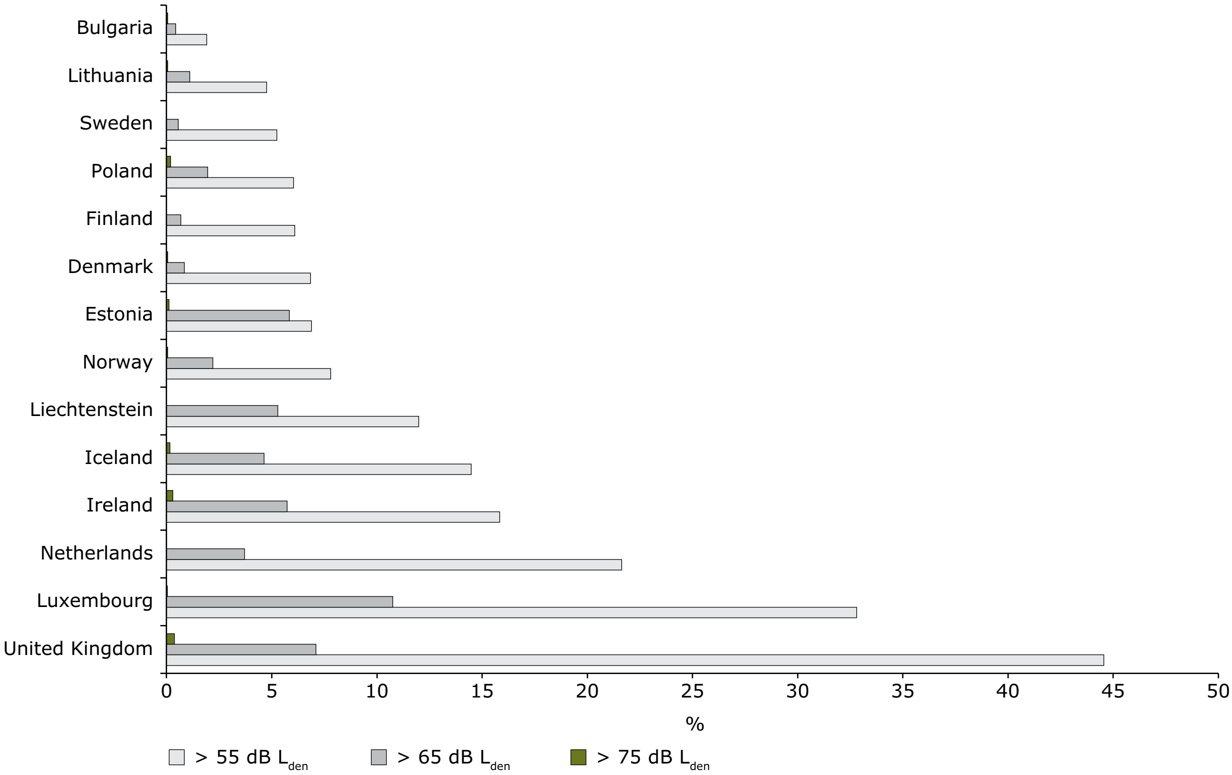
Note: (a) Austria, Germany, Malta, Slovakia, Spain, Switzerland: Exposure information under review.

(b) France: Exposure information considered incomplete (information reported considering solely major roads from 3 to 6 million vehicles).

Estonia: Provision of information on exposure to major roads including agglomerations solely.

Belgium, Croatia, Cyprus, Czech Republic, Greece, Hungary, Italy, Latvia, Portugal, Romania, Slovenia, Turkey: Data not provided.

Figure 3.11 Percentage of people exposed to major roads > 3 million vehicles/year including agglomerations, L_{den}, over the total population of the country (2012)



Note: Austria, France, Germany, Malta, Slovakia, Spain, Switzerland: Exposure information under review.

Belgium, Croatia, Cyprus, Czech Republic, Greece, Hungary, Italy, Latvia, Portugal, Romania, Slovenia, Turkey: Data not provided.

3.3 Other sources of noise

3.3.1 Railways

Railways are the second most dominant source of environmental noise in Europe, with nearly 7 million people exposed to levels above 55 dB L_{den} in 2012 considering people exposed both inside and outside urban areas, as reported in August 2013. Estimation — based on calculated figures complementing current reported data to estimate the overall number of people exposed — increases this figure up to nearly 14 million people, doubling the current reported data, with more than 4 million people estimated to be exposed to major railways transport outside urban areas and 9.5 million people estimated to be exposed to railways transport noise inside urban areas (Figure 3.12).

There may be many reasons to explain the differences on the number of people exposed to road traffic noise and to railway traffic noise, such as the length of the road network compared with the length of the railways' network inside as well as outside urban areas. In the case of urban areas, the inclusion or not of urban trams and light railways in the noise mapping calculation, or the fact that the majority of major railway networks in urban areas are located underground are known as important causes of differences in reported amount of people exposed.

With current data reported, 74 % of nearly 4 million people are exposed to railways traffic noise inside urban areas [8] below 65 dB L_{den} and solely 2 % are exposed to more than 75 dB.

The total number of people exposed to railways noise inside urban areas varies between the different countries submitting data in 2012. On average, at European level, 4.65 % of people living inside urban areas are exposed to railways traffic noise

(8) Urban areas with more than 100 000 inhabitants, reaching a total of 270 out of 460 and distributed among 23 EEA member countries.

Figure 3.12 Number of people exposed to railway noise inside and outside urban areas, > 55 dB L_{den}, EEA member countries (2012)

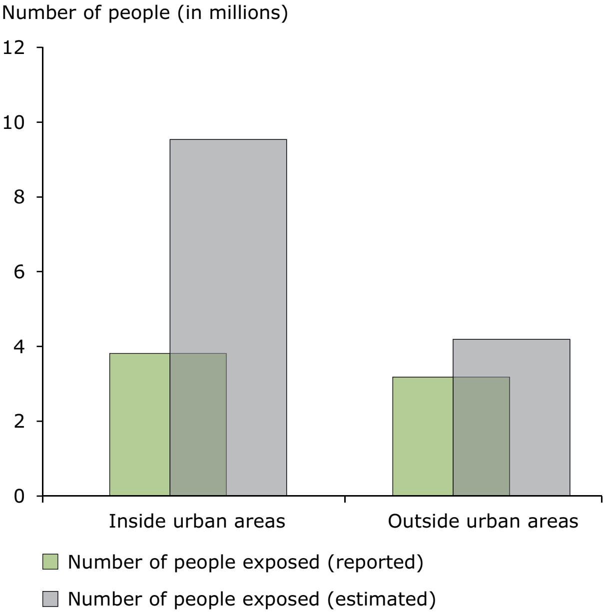


Photo: © Colin Nugent

above 55 dB L_{den}, with Belgium, Finland, France and Norway having more than 5 % of their urban inhabitants exposed to railways traffic noise above 55 dB L_{den}, and Austria, Sweden and Switzerland more than 10 % (Figure 3.14).

The net change at European level of people exposed to railways traffic noise inside urban areas from 2007 to 2012 shows a decrease in the number of people exposed in all five noise bands. This analysis takes into account 68 urban areas with more 250 000 inhabitants that have reported information both in 2007 and 2012 (the incompleteness of the whole data set is an important factor to take into consideration when analysing trends, as they may vary when the complete data set is available). German urban areas, especially in the noise bands from 55–59 dB and from 60–64 dB, are those with higher influence in the overall results at European level, while on the other side, urban areas from Finland, Ireland, Spain and Sweden show a minor increase in the number of people exposed to railways transport noise inside urban areas (Figure 3.13).

Concerning noise from major railways outside of urban areas, the reported data indicates there are a little more than 3 million people exposed to levels above 55 dB L_{den}. This is likely to increase by about a third once assessments are complete for the full expected network of 40 066 km of railways with more than 30 000 train passages per year, however the data underpinning the extent of railways are also likely to be updated.

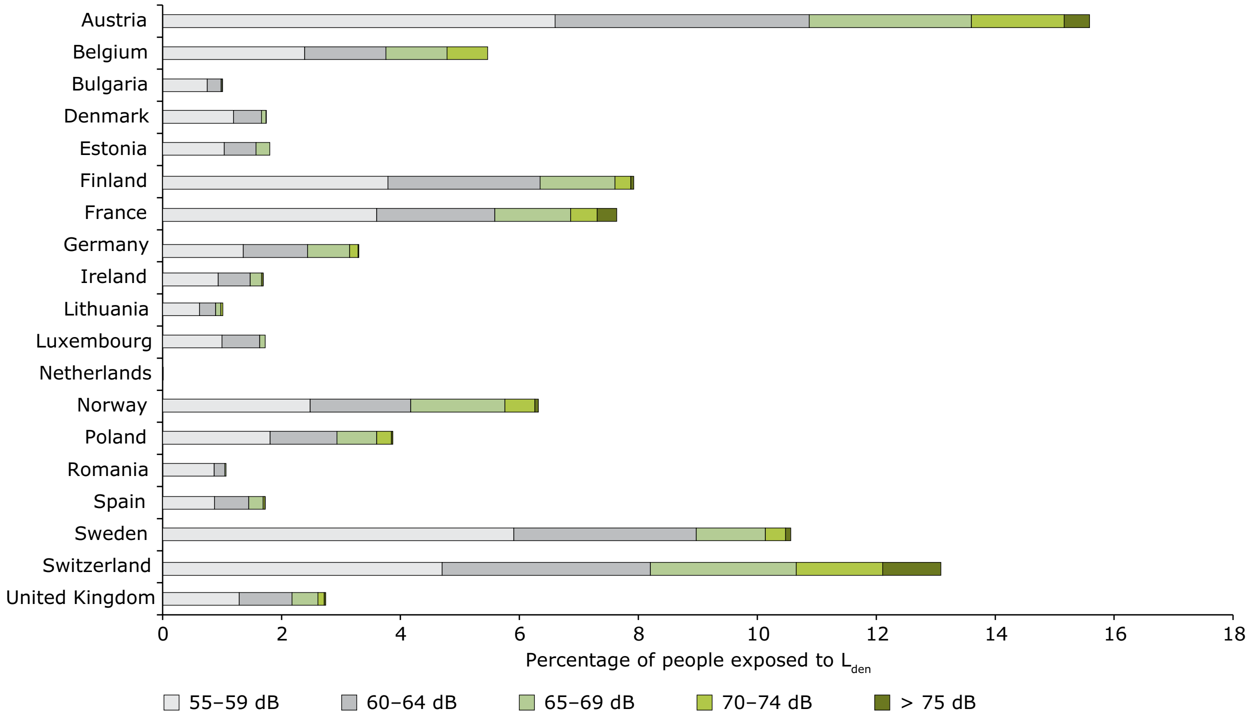
The reported data also indicate that the majority of people exposed to major railways outside urban areas are exposed below 65 dB L_{den} (85 % of the total population exposed to major railways outside urban areas in Europe). Nevertheless, in countries such as Finland, Ireland, Lithuania and Switzerland, this percentage is lower and, consequently, more people are exposed to values above 65 dB than the European average values (Figure 3.15). This great variability on people exposed reflects to some extent the distribution of kilometres between countries and diversity in country sizes, but also how the railways network has been structured not only at country level but also at pan-European level.

As soon as exposure to major railways also considers urban areas, the percentage of people exposed to more than 55 dB L_{den} over the total population of the country increases in all countries, nearly 3 times higher than at European level. The relatively higher importance of the percentage of people exposed above 65 dB and above 75 dB is noticeable. Particularly when the exposure calculations consider people living in urban areas compared with the same calculations not taking urban areas into consideration, as can be seen in Austria and Switzerland (Figure 3.16).

3.3.2 *Airports*

In the context of noise exposure data reported in accordance with the END, aircraft noise affects only

Figure 3.13 Percentage of population exposed to railway noise, L_{den}, in 270 urban areas, EEA member countries (2012)

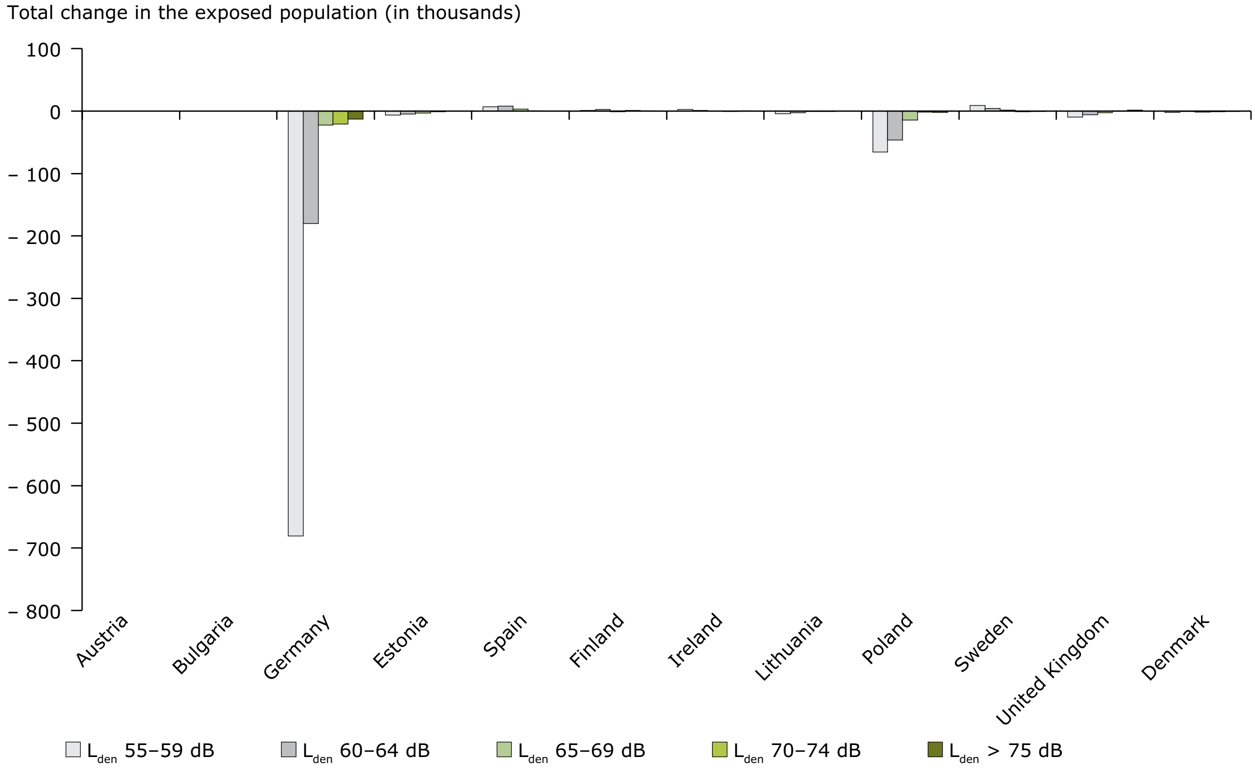


Note: France: Only reported agglomerations from 100 000 to 250 000 inhabitants in 2012.

Liechtenstein: Data not applicable (there is no agglomeration above 100 000 inhabitants in the country).

Croatia, Cyprus, Czech Republic, Greece, Hungary, Italy, Latvia, Portugal, Slovakia, Slovenia, Turkey: Data not provided.

Figure 3.14 Total change of people exposed to railways noise inside agglomerations, L_{den}, at country level (2007–2012)



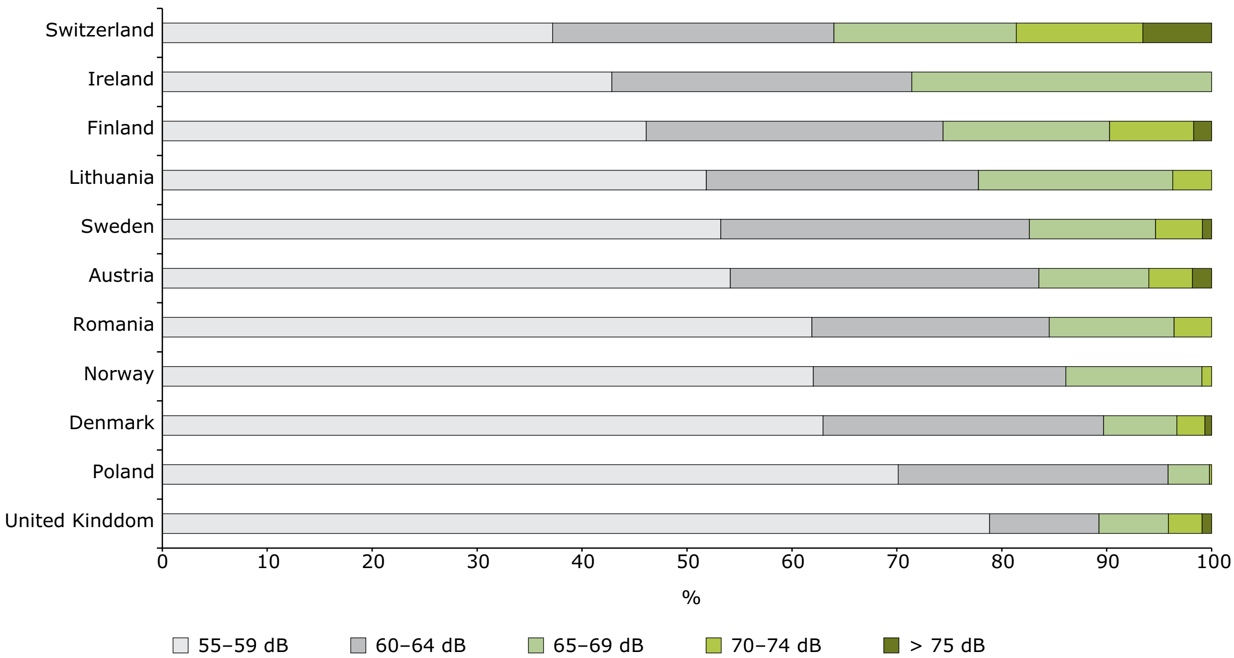
the areas immediately surrounding an airport. This is due to the fact that in many cases the reported END data relates only to airports and often considers only flights either landing or taking off at a particular airport. Any other type of overflight is not commonly considered by the END data. Therefore, the different types of environment in which each airport is located could lead to variations in the number of people exposed. This is of special relevance when analysing people exposed to aircraft noise inside agglomerations and the different abatement measures that could be implemented to tackle the situation.

On this basis, noise from take-offs and landings at airports affects 0.6 million people at European level above 55 dB L_{den} outside urban areas (estimations raise this figure up to 1.25 million people were the data to be complete). This figure represents a much smaller proportion if compared with road and rail traffic noise, although air traffic noise is regarded as more annoying than the other noise sources (ISO, 2003). Despite the technological developments occurring in the last 30 years tackling noise at source, the impact of individual events may be very high given the decibel level that could be achieved by each aircraft. Moreover, the growing volume of air traffic is not helping in the reduction of the number of people exposed to aircraft noise, particularly during the night (EU, 2012).

Inside urban areas, nearly 2 million people are exposed above 55 dB L_{den} due to aircraft noise, as reported in August 2013. In general, there is one agglomeration in each country having, by far, the largest number of people exposed, which in most cases corresponds to the capital city. It is estimated that for all expected airports data, the true figure increases to 3.7 million people exposed above 55 dB L_{den} due to noise from airports.

In the majority of countries, there is only one major airport captured by the END specifications ([10]), which is quite frequently located close to the capital city. In bigger countries, such as France,

Figure 3.15 Distribution of population exposed to major railways > 30 000 train passager per year outside urban areas, L_{den} (2012)



Note: France, Germany, Spain, : Exposure data considered incomplete.

Estonia: Only provision of information on exposure including agglomerations.

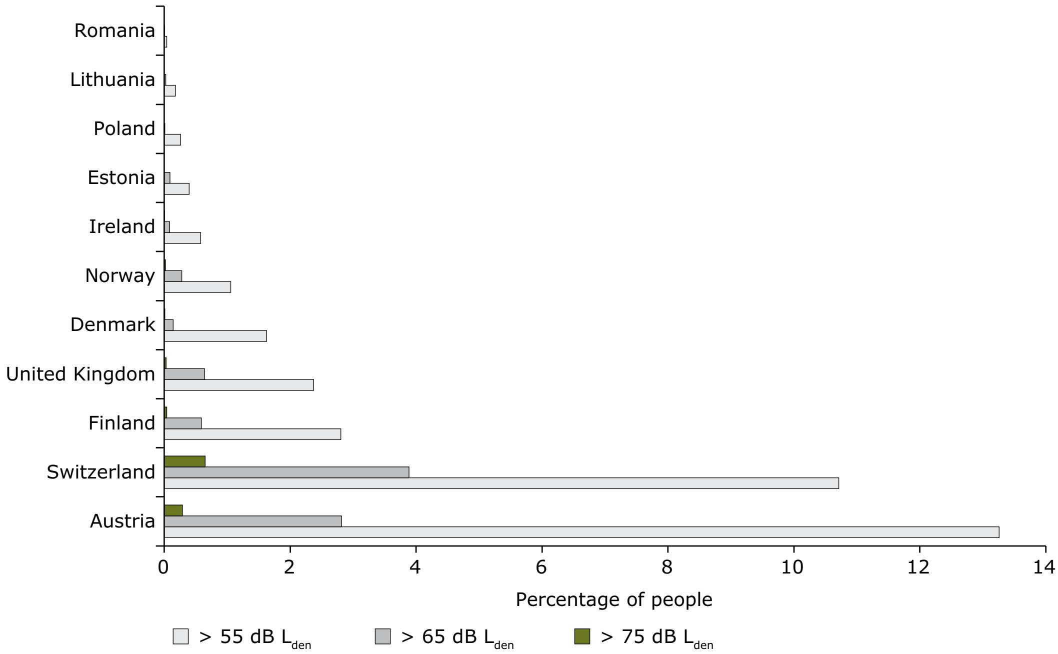
The Netherlands, Luxembourg: Information on noise sources not being updated.

Belgium, Czech Republic, Greece, Croatia, Hungary, Italy, Latvia, Portugal, Slovenia, Slovakia, Turkey: Data not provided.

Bulgaria, Cyprus, Iceland, Liechtenstein, Malta: Data not applicable (no major railways above 60 000 train passages/year).

([10]) 'Major airport' shall mean a civil airport, designated by the Member States, which has more than 50 000 movements per year (a movement being a take-off or a landing), excluding those purely for training purposes on light aircraft.

Figure 3.16 Percentage of people exposed to major railways > 30 000 train passages/year including agglomerations, L_{den}, over the total population of the country (2012)



Note: France, Germany, Spain: Exposure data considered incomplete.

Luxembourg, the Netherlands: Information on noise sources not being updated.

Belgium, Croatia, Czech Republic, Greece, Hungary, Italy, Latvia, Portugal, Slovakia, Slovenia, Turkey: Data not provided.

Bulgaria, Cyprus, Iceland, Liechtenstein, Malta: Data not applicable (no major railways above 30 000 train passages/year).

Germany, Spain and the United Kingdom, more than one major airport is identified and therefore reported, so agglomerations other than the capital city have people exposed to aircraft noise. Countries with larger agglomerations and with higher numbers of inhabitants at country level will have more people exposed to aircraft noise inside urban areas, but this variability will also depend on aircraft traffic volumes, on local factors such as location and surroundings of the airport, and even on population density at country level. This means that urban areas with the highest number of people exposed do not systematically coincide with the agglomerations with the highest percentage of people exposed above 55 dB L_{den} due to aircraft noise (Figure 3.17).

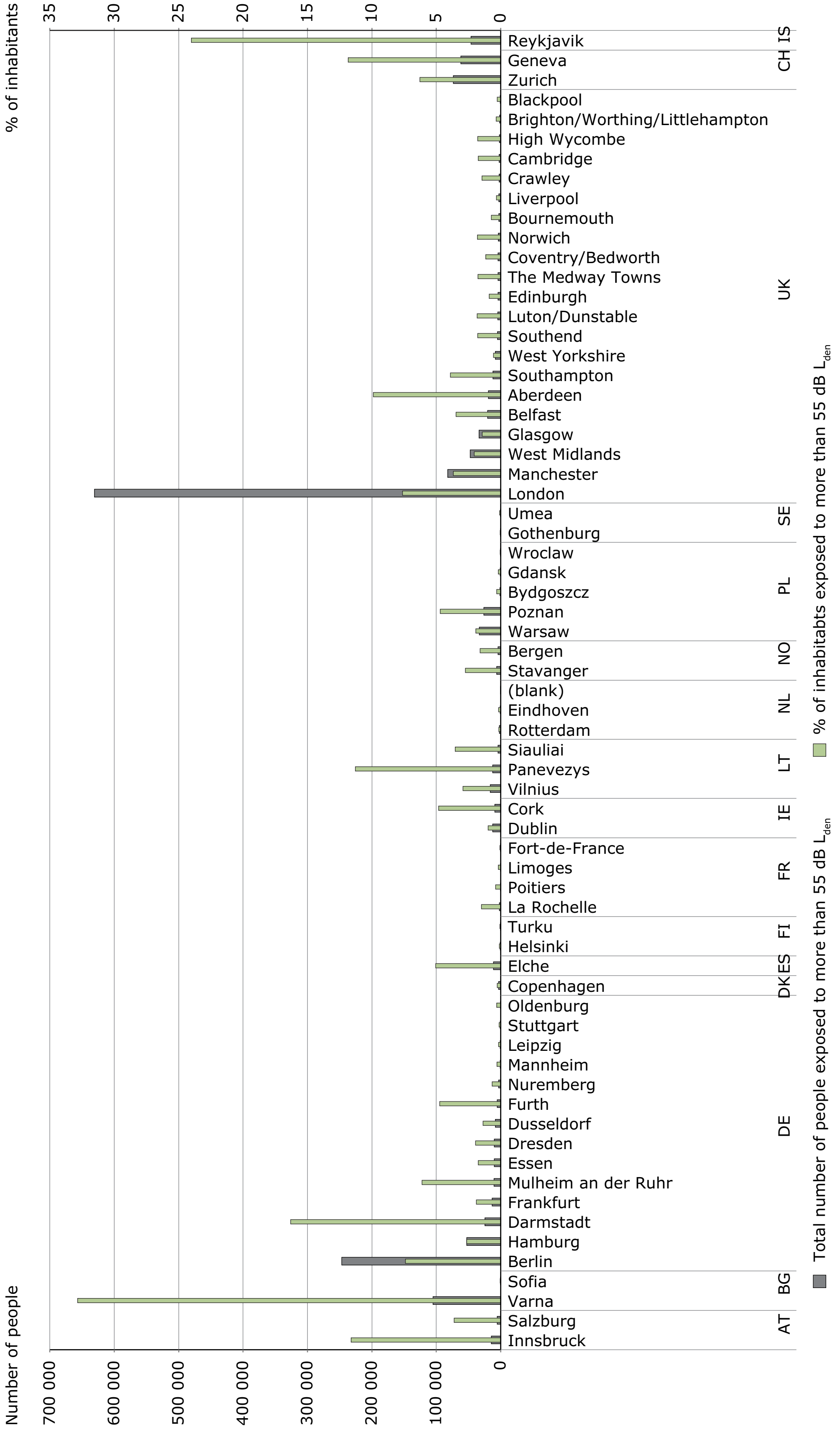
Trends in exposure to airport noise are illustrated in Figure 3.18. It is evident that some countries have calculated a significant reduction in the numbers of people affected by noise from major airports between the two noise mapping rounds. Where increases are observed, the scale of change is much less marked. This analysis takes into account 46 major airports with more than 50 000 movements/year that reported information on people exposure in 2007 and updated it again in 2012.

3.3.3 *Industry*

Around 300 000 people living in urban areas ([11]) are exposed above 55 dB L_{den} due to industrial noise in Europe. Estimation — based on calculated figures complementing current reported data to estimate the overall number of people exposed — increases this figure up to 1.4 million people to be exposed above 55 dB L_{den} due to industrial noise. So, industrial noise is, by far, the noise source presenting the lower values on population exposed (in totals and in percentages) compared with the rest of the noise sources being reported under the END requirements.

([11]) 44 % of urban areas above 100 000 inhabitants have yet to report data on industrial noise exposure.

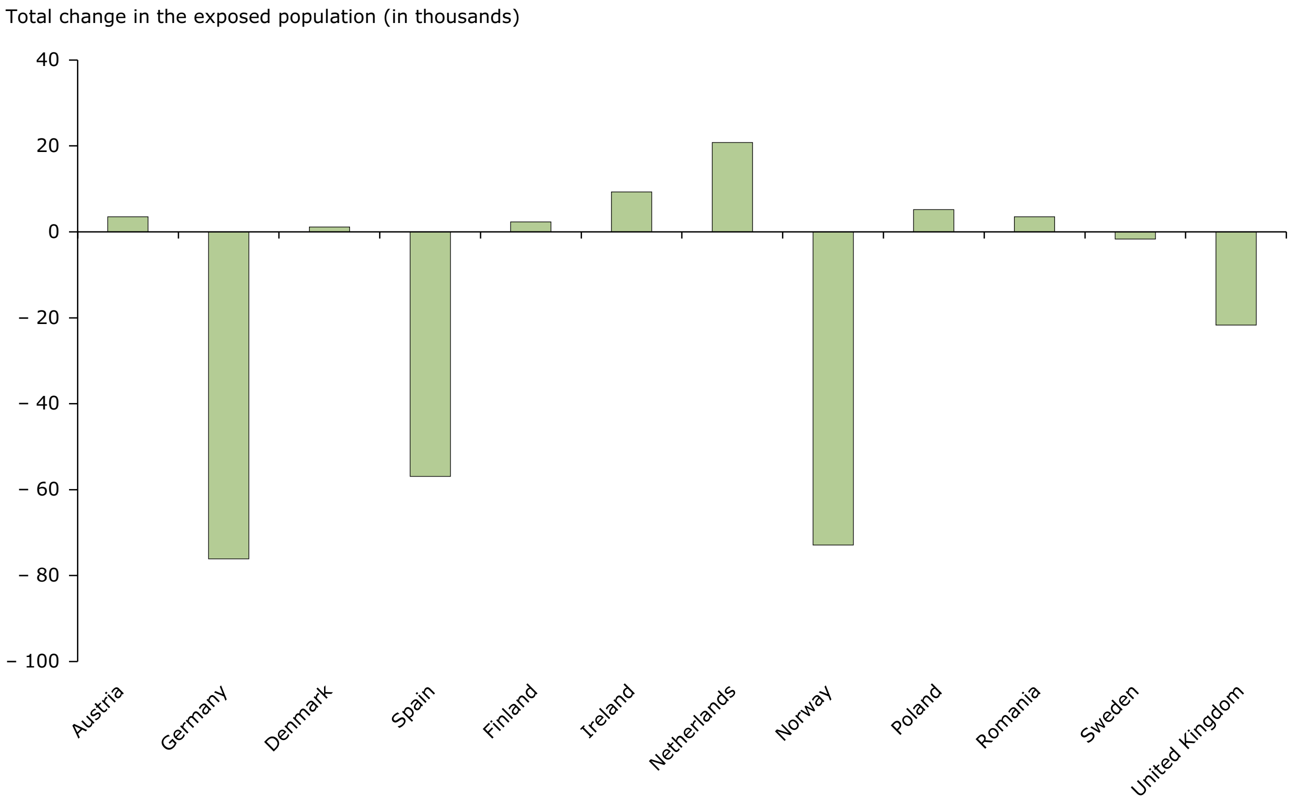
Figure 3.17 Number of people exposed to airport noise L_{den} > 55 dB per agglomeration total and percentage (2012). Agglomerations sorted by country, then by number of people exposed



Note: Countries not providing information concerning any urban areas have been excluded from the figure.

Country codes (based on Eurostat country codes at 1 June 2012: see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Country_codes): AT (Austria), BG (Bulgaria), CH (Switzerland), DE (Germany), DK (Denmark), ES (Spain), FI (Finland), FR (France), IE (Ireland), IS (Iceland), LT (Lithuania), NL (the Netherlands), NO (Norway), PL (Poland), SE (Sweden), UK (the United Kingdom).

Figure 3.18 Total change of exposed population to major airport noise including urban areas, > 55 dB L_{den} (2007–2012)



For the remaining environmental noise sources evaluated, the majority of people are exposed to the lowest band, reaching in this case 74 % of the total exposed population solely considering exposure to noise values from 55–59 dB (Figure 3.19).

Percentages of people exposed to industrial noise at urban area level reach a mean value at European level of 0.42 % of the total population living in those urban areas ([12]) (urban areas reporting '0 value', which represents 'less than 100 people exposed', have also been taken into consideration). Cases such as Klaipeda (with 20 400 people exposed to industrial noise, representing 12.6 % of the total population) and Gdynia (with 6 400 people exposed to industrial noise, representing 7.2 % of the total population), or on the other side London (with 16 800 people exposed to industrial noise but representing 0.2 % of the total population) are examples of outstanding cases where local specificities should be evaluated and taken into account for a more detailed analysis at urban area level.

Evaluating the changes occurring from 2007 to 2012 at European level, a net decrease in the number of people exposed is happening, especially in the lower noise bands. This analysis takes into account 65 urban areas with more 250 000 inhabitants that have reported information both in 2007 and 2012. However, when analysing data at country level, people exposed from 55–59 dB is slightly increasing in Estonia, Lithuania and Poland, while again the United Kingdom is the country mainly influencing the results at European level (Figure 3.20).

([12]) 245 urban areas with more than 100 000 inhabitants have been taken into account to calculate the European average.

Figure 3.19 Number of people exposed to industrial noise inside agglomerations > 100 000 inhabitants, L_{den}, EEA member countries (2012)

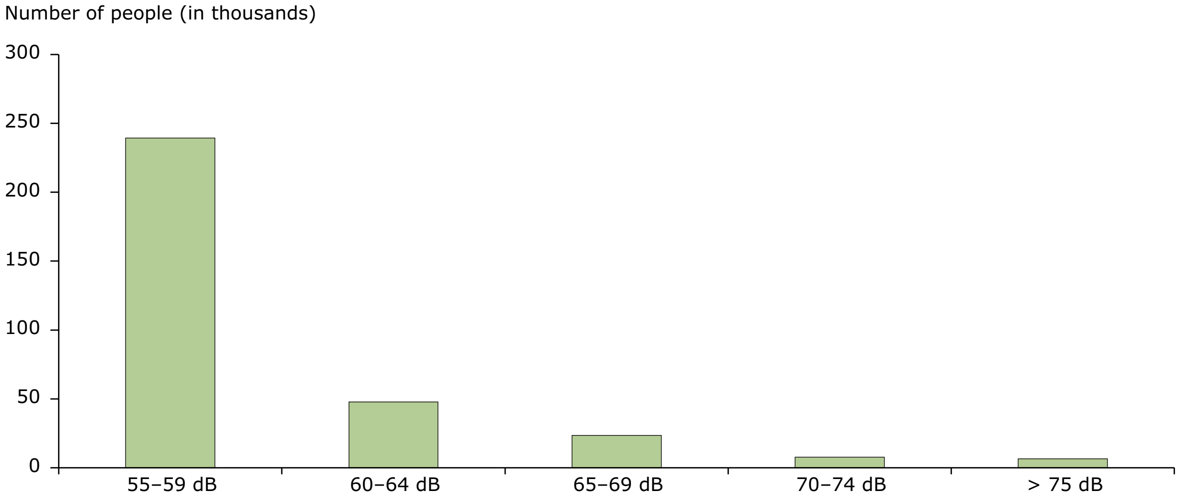
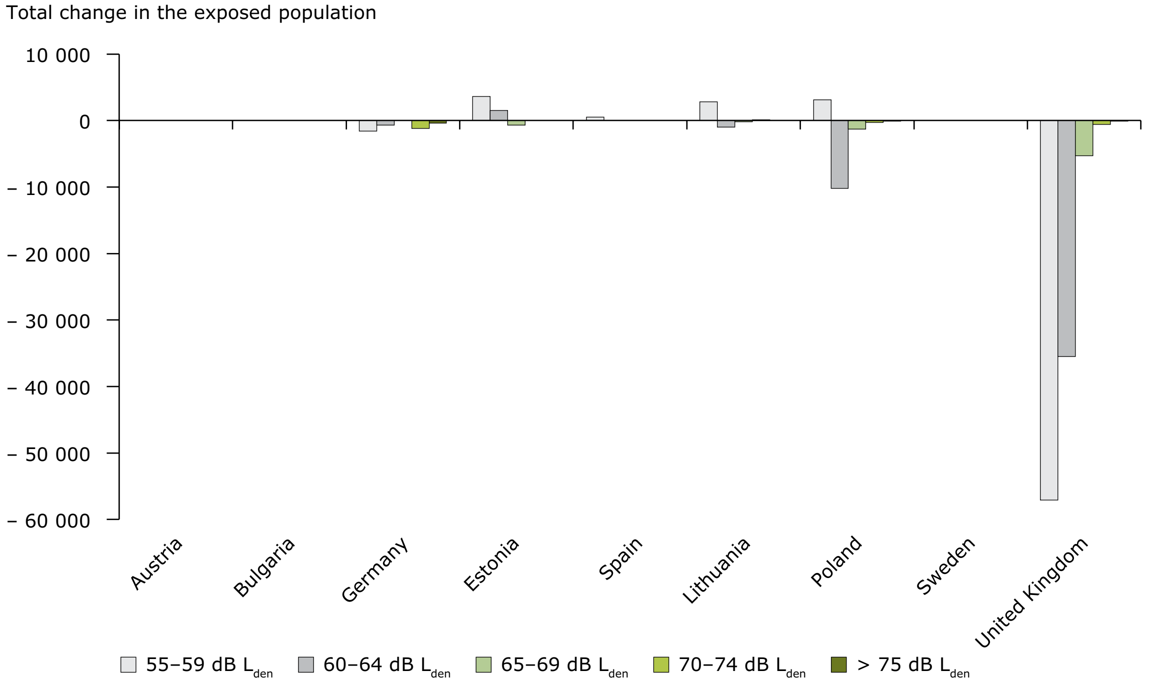


Figure 3.20 Total change of people exposed to industrial noise inside agglomerations, L_{den}, at country level (2007–2012)



Box 3.5 Up-to-date noise data

The END permits Member States to implement noise mapping using modelling or measurement techniques. In all instances, the noise mapping data reported to EEA has been calculated using a modelling method, although it is acknowledged that some noise mapping projects may utilise measurements to validate the outputs from the models.

With the sometimes large variations in the timeliness of reporting data by Member States and uncertainties about the comparability of input data used in the modelling process, the EEA has identified the need to make available more up-to-date data relating to environmental noise in Europe. To this end, a near-real-time exchange of data is underway that derives data from official measurement stations.

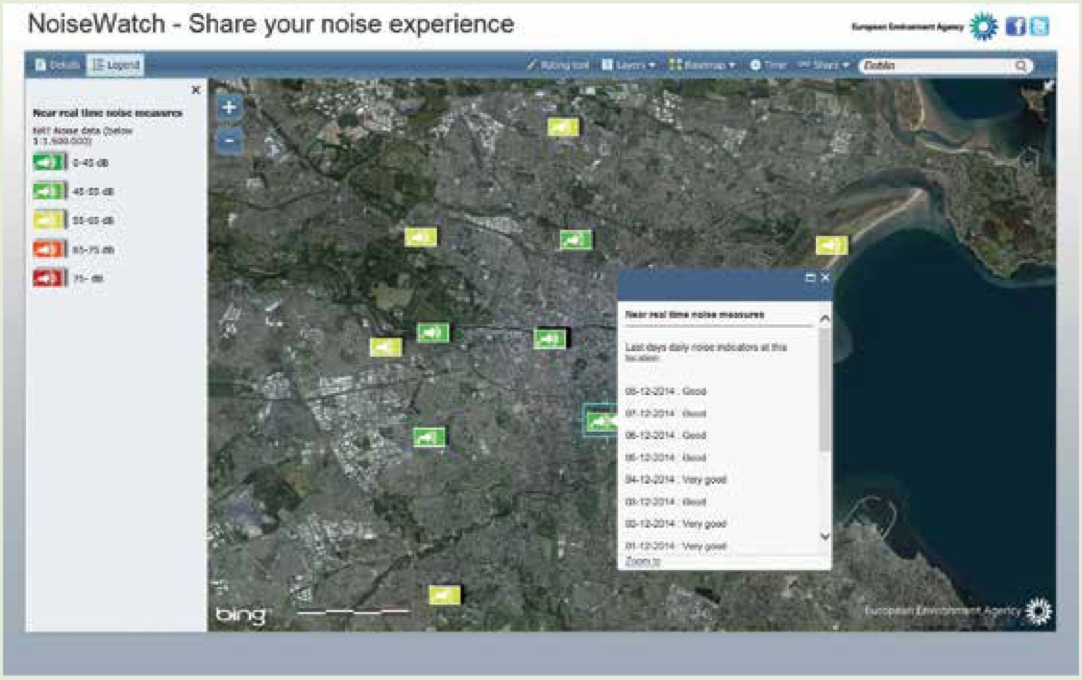
The first exchange has been conducted with the cooperation of Dublin City Council and is currently delivering near-real-time noise data to the EEA for up to 15 permanent noise monitoring stations located around the city of Dublin (Figure 3.21).

These data are converted into ratings as are more than 194 000 mobile device measurements that have been reported since December 2011.

The modelled city ratings and measurement station outputs are considered robust sources of data. The mobile ratings are based upon measurements made using mobile devices on iOS and Android platforms. Whilst many of these devices offer measurement capabilities comaparable to dedicated instrumentation, it cannot be guaranteed that proper measurement protocol has been observed in each instance. The source tagging offered by this data can, however, be described as a robust dataset.

From this we know that reports by data providers in Europe show that almost 57 % of ratings correspond to road traffic noise. Aircraft noise accounts for 15 % of ratings, while railway noise is attributable to almost 12 % of ratings. Where noise from industrial sources is concerned, almost 17 % of ratings in Europe relate to this source (EEA, 2014b).

Figure 3.21 Noise ratings at measurement stations, Dublin



In comparison to END data, the dominance of road traffic noise is also reflected by the ratings, indicating clearly that road noise is a source of concern in Europe.

Ratings for rail and aircraft noise are at similar levels in comparison to END data. What is surprising though, is the relatively high number of ratings attributable to industrial noise. Where END data are concerned, industrial noise is very much the source with least exposure, but in terms of ratings it is ranked second only to road traffic in terms of ratings by data providers.

4 Impacts of noise exposure — health impact assessment

4.1 Relationships between noise exposure and health and well-being effects

Noise exposure from transport sources and industry can lead to annoyance, sleep disturbance, and related increases in the risk of hypertension and cardiovascular disease. Hypertension and cardiovascular disease are important risk factors for premature mortality, so exposure to noise pollution can also indirectly reduce life expectancy. Noise exposure has also been shown to cause a significant negative effect on the cognitive performance of schoolchildren (Basner et al., 2014).

For most of the aforementioned health effects, so-called exposure–response relations are available or can be derived from risk estimates reported in the epidemiological literature. Exposure–response relations describe the change in frequency of the health and well-being effects as function of noise exposure.

A number of recent research activities have addressed the health effects of environmental noise, such as the publication of position papers on annoyance and transportation noise and on sleep disturbance and transportation noise, and the funding of multi-centre projects on the health effects of noise among children (RANCH, Stansfeld et al., 2005) and among adults (HYENA, Jarup et al., 2005), as well as the EU Network on Noise and Health project (ENNAH, Stansfeld and Clark, 2011). WHO publications include the 'Night noise guidelines for Europe' (WHO, 2009) and the 'Burden of disease from environmental noise' (WHO, 2011). Information from these research activities and documents has among other activities been used to create exposure-response relations for environmental noise, together with information from other epidemiological studies. The EEA has also published guidance on how to consider health impact evidence in the context of END action plan development (EEA, 2010).

Table 4.1 shows the health and well-being effects for which an exposure–response relation based on a pooled analysis or a meta-analysis of several studies is available, and which are applied in this report.

The reported exposure distributions for road traffic, railway, aircraft and industry noise in 2011 were used in combination with these selected exposure-response relationships to estimate the impact on various health and well-being end points for residents in the EEA member countries

Table 4.1 Core characteristics of the applied exposure-response relations

Health and well-being effect	Population	Reference
(Severe) annoyance	Adults	Road traffic and railways: Miedema and Oudshoorn, 2001; industry: Miedema and Vos, 2004; aircraft: Janssen and Vos, 2009
(Severe) sleep disturbance	Adults	Road traffic, railways and industry: Miedema and Vos, 2007; aircraft: Janssen and Vos, 2009
Reading impairment	7 to 17-years old	Only aircraft: adapted from Clark et al., 2006
Hypertension	Total population	Road traffic, railways and industry: Van Kempen and Babisch, 2012; aircraft: Babisch and Van Kamp, 2009
Coronary heart disease (mortality and morbidity)	Total population	All sources: Vinneau et al., 2013
Stroke (mortality and morbidity)	Total population	All sources: ad hoc meta-analysis based on 6 studies (Huss et al., 2010; Sørensen et al., 2011; Hansell et al., 2013; Correia et al., 2013, Floud et al., 2013; de Kluizenaar et al., 2013)

that reported data. Unlike in the previous chapter addressing noise exposure, no gap-filling has been used in the health impact assessment, meaning that total impacts of noise exposure in Europe will be greater than the numbers presented here.

The estimations for annoyance, sleep disturbance and reading impairment were made for sub-groups of the total population (adults and children 7–17 years old). For hypertension, coronary heart disease and stroke, the results are reported for the total population.

Annoyance and sleep disturbance can be estimated directly by combining the noise exposure distributions with exposure–response relationship (and the relevant fraction of the population). The exposure–response functions are source-specific and are based on a pooled analysis of several studies, with the exception of industrial noise. For this source, the relationship is based on a study in the Netherlands based upon eight industrial sites (Miedema and Vos, 2004). Since no studies on sleep disturbance and industrial noise have been carried out, the available relation for road traffic noise was applied, given the similarity of the exposure–response relations for (severe) annoyance from road traffic and industry noise. For the health impact assessment, the statistical relations published in the original papers instead of the commonly applied polynomials (European Commission, 2002 and 2004) were employed. Updated exposure–response relations for aircraft noise based on post-1990 studies (Janssen and Vos, 2009) were used, since there are clear indications that the exposure–response relationship for aircraft noise has become more pronounced over time.

The results of the RANCH study on reading comprehension were also re-analysed in order to derive an exposure–response relation for reading impairment (adopted from Clark et al., 2006 and Van Kempen, 2008).

In the WHO guidelines on community noise (WHO, 1999), it was concluded that epidemiological studies show that cardiovascular effects occur after long-term exposure to noise with $L_{Aeq,24hr}$ values of 65–70 dB. $L_{Aeq,24hr}$ is the equivalent noise level over a 24-hour period. Since that time, a number of studies have been published on the association between environmental noise and the prevalence of hypertension and the incidence of coronary heart disease (including myocardial infarction) and stroke. For hypertension, the result of the meta-analysis on road traffic noise of Van Kempen and Babisch (2012) was applied for all sources, except for aircraft noise for which a specific result is available (Babisch and Van Kamp, 2009). Recently, Vienneau et al. (2013) carried out a meta-analysis with eight cohort and case-control studies on the incidence and the mortality of coronary heart disease. There is good evidence that hypertension is not only associated with a higher risk for coronary heart disease, but also with a higher risk for stroke. Since 2010, a number of studies have been published that investigated the association between noise exposure and the risk of stroke (Huss et al., 2010; Sørensen et al., 2011; Hansell et al., 2013; Correia et al., 2013; Floud et al., 2013; de Kluizenaar et al., 2013). An 'ad hoc' meta-analysis for stroke was carried out with the results of these six studies since a published meta-analysis was not available. For the combination of incidence and mortality, a relative risk of 1.04 (95 %CI: 1.00–1.09) per 10 dB increase in noise exposure was derived, which is similar to the risk for coronary heart disease reported by Vienneau et al. (2013). The results of the four meta-analyses suggest that the increased risk for hypertension and cardiovascular disease starts at levels of 50 dB L_{den}.

For hypertension and cardiovascular disease, the health impact depends among others on the 'base-line' prevalence (frequency) or incidence (new cases per year). These differ between countries and were taken into account in the calculations. For reading impairment, for which the health impact assessment was restricted to aircraft noise, the baseline frequency was fixed (10 %).

The methods employed for this health impact assessment are described in more detail in Houthuijs et al. (2014).

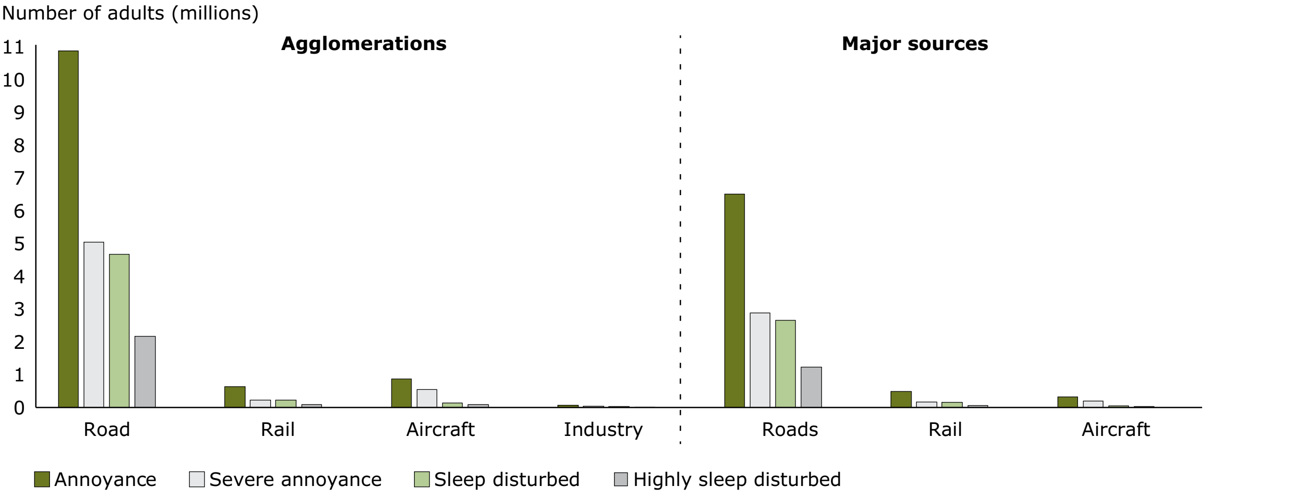
4.2 Annoyance and sleep disturbance

Based on the available data reported by countries for 2011, around 19.8 million adults living in agglomerations or near major sources with noise levels equal to or above 55 dB L_{den} may be considered as being 'annoyed' by noise from road traffic, railways, aircrafts or industry; 9.1 million of them are 'highly' annoyed.

It is similarly estimated that 7.9 million adults have sleep disturbance due to night-time noise from road traffic, railways, aircrafts or industry; 3.7 million of them are severely sleep disturbed. In Figure 4.1, the results for annoyance and sleep disturbance are presented according to the noise source and the location of the assessment.

As shown in the figure, the majority of the burden of annoyance and sleep disturbance is related to road traffic noise (about 90 %), of which about 65% occurs

Figure 4.1 Estimated number of adults with (severe) annoyance and estimated number of adults that are (highly) sleep disturbed according to noise source and location of the assessment



in agglomerations. Airport noise is the second largest source of annoyance and sleep disturbance.

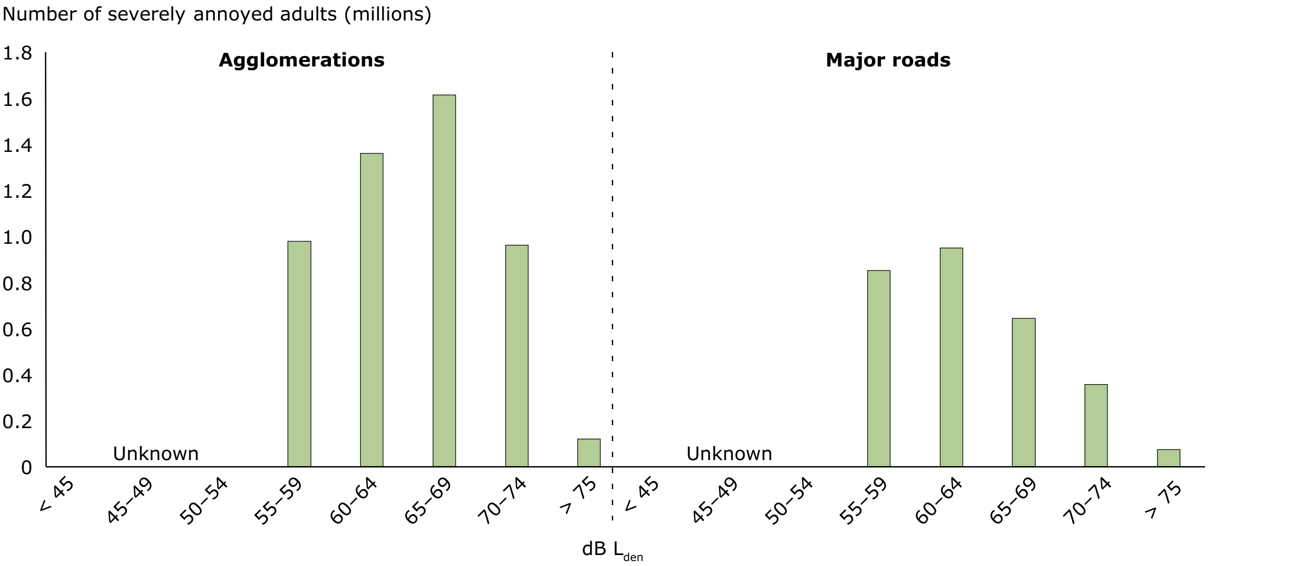
In Figure 4.2, the number of adults with severe noise annoyance due to road traffic is shown per 5 dB L_{den} exposure category for agglomerations and near major roads.

The largest number of adults with severe annoyance in agglomerations can be found in the 65–69 dB L_{den} category (1.6 million adults). The distribution for major roads is shifted to lower categories, with the highest numbers in the 60–64 dB L_{den} category (950 000 adults). The distributions in Figure 4.2 suggest that a substantial part of the burden of severe annoyance can take place at levels below 55 dB L_{den}.

4.3 Reading impairment, hypertension, and cardiovascular disease and premature mortality

The exposure to environmental noise contributed to about 910 000 additional prevalent cases of hypertension in 2011. These are primarily related to

Figure 4.2 Estimated number of adults with severe annoyance due to road traffic noise according to L_{den} exposure category and location of the assessment



road traffic noise (790 000 prevalent cases), as can been seen in Figure 4.3.

It is estimated that almost 8 000 school children (aged 7–17 years) have a reading impairment due to exposure to noise from aircraft operations at airports.

The total number of hospital admissions related to coronary heart disease and stroke is estimated to be 43 000 per year due to noise. This is about four-fold higher than the number of premature deaths. Noise exposure could contribute to a total of about 6 700 premature deaths per year due to coronary heart disease and about 3 300 premature deaths due to stroke. Road traffic noise is the main source: 8 900 of the estimated 10 000 premature deaths per year (89 %) are attributable to road traffic noise exposure.

In Figure 4.4, the estimated cases of road traffic-related premature mortality per year are shown according to the L_{den} exposure category and the location of the assessment.

Similar to Figure 4.2, the largest burden in agglomerations can be found in the 65–69 dB category and nearby major roads in the 60–64 dB category.

The hospital admissions due to cardiovascular disease lead to 17 000 years lived with a disability each year, and the premature mortality to approximately 156 000 years of life lost each year.

4.4 Discussion

The health effects addressed in the preceding sections are considered as being the most investigated non-auditory health end points of noise exposure. Other potential health end points relevant to noise exposure have recently been reported, such as diabetes (Sørensen et al., 2013) and breast cancer (Sørensen et al., 2014). Although a possible impact of noise on these end points is biologically plausible, the findings of recent observational studies investigating these end points need confirmation before they can be considered in future health impact assessments.

Although almost 90 % of the health impact is related to road traffic noise exposure, the current assessment may reflect only 20–35 % of the total impact of road traffic noise in the EEA-33. Incomplete data from countries, and limitation of the noise assessment to agglomerations and major sources and to levels above 55 dB L_{den} or above 50 dB L_{night} are causes for underestimation. The size of the underestimation is not known for other sources of noise.

The burden of the health effects of road traffic noise can be found in agglomerations in the 65–69 dB and nearby major roads in the 60–64 dB category. These results suggest that measures only aimed at reducing health risks of high noise levels, like noise insulation, are not effective to reduce the total burden of disease due to road traffic noise.

Figure 4.3 Estimated number of prevalent cases of hypertension according to noise source and location of the assessment

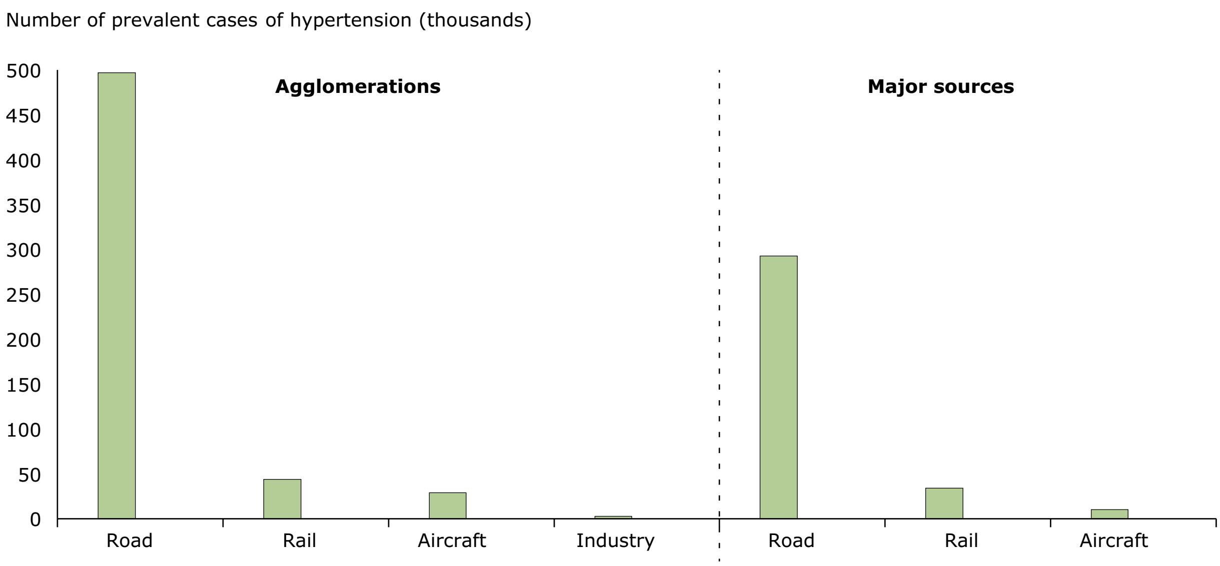
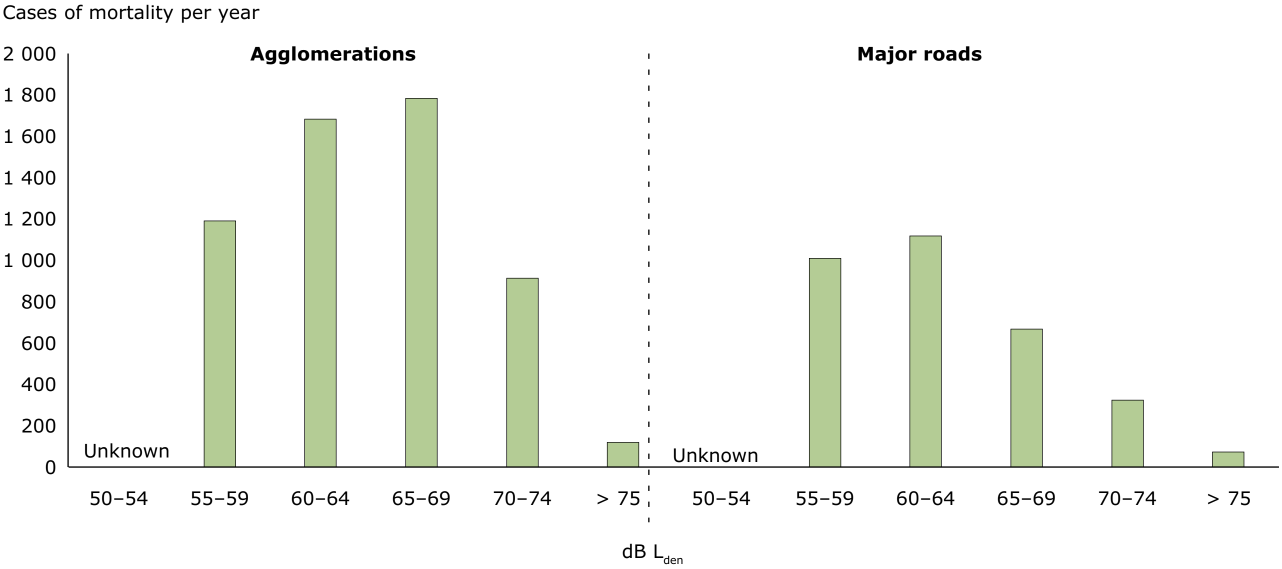


Figure 4.4 Estimated cases of road traffic-related premature mortality per year due to noise exposure according to L_{den} exposure category and location of the assessment



The reported numbers encompass many uncertainties. The major sources of uncertainties are in the exposure–response relations, the transferability of the (often international) relations to individual countries of the EEA-33, the comparability of the baseline data on hypertension, coronary heart disease and stroke between countries, and the assumption about the demographic build-up of the areas where the noise assessment took place. The importance and the magnitude of the uncertainties vary from health end point to health end point.

Box 4.1 Night Noise Guidelines for Europe

In 2009, the WHO published its Night Noise Guidelines (NNGL) for Europe (WHO, 2009), in which 40 dB L_{night} was declared as night noise guideline. Where this was not achievable in the short term, an interim target of 55 dB L_{night} outside was suggested.

The rationale for the guidelines were based upon the effects of sleep disturbance due to noise, such as body movements, awakening and self-reported sleep disturbance, starting at levels below 40 dB L_{night} and effects on the cardiovascular system starting above 55 dB.

Since the publication of the WHO report, a number of additional studies have been published on the cardiovascular effect of environmental noise suggesting that an elevated risk for hypertension, coronary heart disease and stroke may take place at levels of 50–55 dB L_{den}. It is not known to what extent daytime and night-time noise levels independently contribute to this increased risk.

Since in agglomerations night-time noise levels from road traffic are approximately 7–10 dB(A) lower than daytime noise levels, and daytime and night-time levels are highly correlated, more residents are part of the noise mapping on the basis of L_{den} exposure (above 55 dB L_{den}, the lowest level assessed under the END) than on the basis of their L_{night} exposure (above 50 dB L_{night}).

Since noise-induced health effects can already start at low L_{den} levels and the night-time noise exposure is included in the L_{den}, the number of residents within an L_{den} assessment is considered a better indicator for the total health impact of environmental noise (including the effects of night-time noise) than the number of residents in an L_{night} assessment. For this reason, the focus of this report is predominantly on L_{den}. However, this should not be interpreted as that night-time noise exposure is not relevant for health and sleep (WHO, 2009).

The ENDRM accommodates the reporting of noise mapping exposure assessments in line with the NNGL level of 40 dB, but to date only a few EEA member countries have responded with these data.

5 Reducing and managing noise exposure

By 2020 it is estimated that approximately 80 % of Europeans will be living in urban areas, with road transport being responsible for a significant fraction of environmental pollution, including noise (EEA, 2013). Environmental impacts associated with road traffic are projected to affect larger areas and larger numbers of people, with the consequent need for such impacts to be managed in order to mitigate negative environmental impacts in Europe's urban areas.

This can be done by, for example:

- access controls to manage the relationship between residents and traffic (especially in city centres);
- management including pedestrianisation, parking and loading controls, delivery time windows, etc.;
- promotion of the use of low(er)-emission vehicles, based on vehicles' emissions performance;
- integration of different traditional transport modes in the mobility policy such as bike sharing, car sharing and ride sharing;
- supporting modal shift to an increased share of walking and cycling, and the development of a good and accessible public transport network;
- development of a sustainable urban mobility plan, which needs to be aligned with urban development plans to ensure that neither is in conflict (EEA, 2013).

So, in order to significantly reduce people's exposure to road traffic noise, noise-abatement measures should be integrated into European mobility and land-use planning action programmes from now on, as noise considerations have often been neglected during planning processes and transport decisions (ERF, 2004).

5.1 Action plans

The END requires action plans to be drawn up for the major transport sources and the largest urban areas, which should aim to reduce the impact of noise upon the affected population. Not only that, but where areas are found to be of a high acoustic quality, in other words, free from noise pollution, they should also be protected by appropriate action plans.

These action plans were to have been drawn up by 18 July 2008 for first-round noise mapping assessments and then again by 18 July 2013 for second-round noise mapping assessments. The third round of action plans is expected to follow this 5-year cycle and be drawn up by 18 July 2018.

In the END an action plan is designed to manage noise issues and effects, including noise reduction if necessary'.

Acoustical planning is defined in the END as 'controlling future noise by planned measures, such as land use planning, systems engineering for traffic, traffic planning, abatement by sound insulation measures and noise control of sources'.

The control of noise at source in transport is, for instance, one key area where the European Commission may also act in relation to defining emission limits for modes of transport.

The minimum requirements for action plans are set out in Annex V of the END.

5.1.1 Quiet areas in agglomerations

The END acknowledges the need for preventing or reducing environmental noise levels that may negatively affect human health, including annoyance and sleep disturbance. In addition, it highlights the need to preserve 'environmental noise quality where it is good', i.e. to protect quiet areas. The foundation for preserving these quiet areas was laid through the Green Paper on Future

Box 5.1 Noise action plans

The type of measures planned in action plans of the first reporting round are very much linked to the noise source.

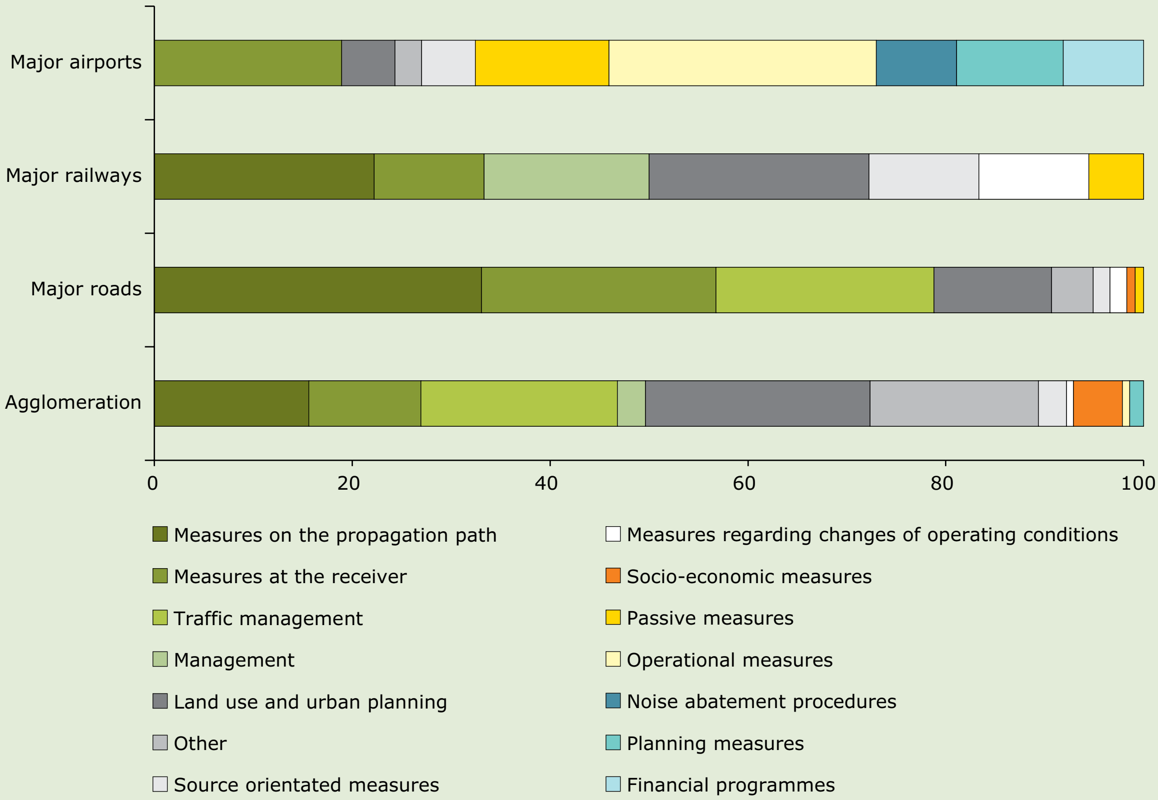
In the case of urban areas, information is currently available for 40 % of the cities. Groups of actions referring to land use and urban planning are the predominant ones. This kind of action is presented in 23 % of all actions plans related to agglomerations. Followed by measures related to traffic management (20 %) and others (17 %), this last one includes measures related to increasing public awareness, avoiding the generation of additional traffic and promoting public transport, and encouraging cycling and walking. The high percentage of measures related to traffic and transport in actions plans linked to agglomerations underlines the importance of these topics as noise sources inside agglomerations.

In the case of major roads, the actions that predominate are those related to measures on the propagation path (32 %), at the receiver (23 %), on traffic management (22 %), and on land use and urban planning (12 %).

Major railways differ from major roads, although propagation path (22 %) and land use and urban planning (22 %) are also included inside the most predominant actions, and measures at the receiver are presented in less than 15 % of the actions plans related to railways. Measures of traffic management presented in major roads are replaced by other specific railways management actions (17 %) such as tram track improvements.

In the case of major airports, the actions highlighted are those considered as operational (presented in 27 % of the actions plans related to major airports) followed by measures at the receiver (19 %).

Figure 5.1 Analysis of END action plan measures



This analysis is based upon reported information and is limited by the data format. In cases where the ENDRM has not been used, it may not be possible to make a comparative analysis of the measures reported.

Box 5.2 Thinking outside the box on noise

Not all action against noise pollution is taking place within the context of END strategic action plans. Through the European Soundscape Award, the EEA aims to disseminate innovative action on noise as implemented at local, regional or national level in the Eionet of countries.

Many of these actions are effective and very easily replicated in other areas of Europe.

The most productive action on road traffic noise is to tackle the problem at source. Reducing vehicle emission limits can be effective, but only if it is based upon an appropriate test methodology, and even then a new limit may take many years before it is represented in the European vehicle fleet. On most of Europe's major roads, the key source of traffic noise comes from the tyre interaction with the road surface. If drivers were to fit quieter tyres to their vehicles, then the noise benefits would be realised immediately. There are requirements for labelling tyres, but how does a consumer find the right low-noise tyre for his or her vehicle? A project in Switzerland has come up with the answer: a multimedia awareness campaign on the issue of tyre noise and a user-friendly database allowing consumers to access the quieter tyres that fit their vehicle. Available online and in three languages, it empowers the consumer to offer an almost instant solution to road traffic noise from individual vehicles in Europe.

Learn more at http://www.reifenetikette.ch/#home and access the quiet tyre list directly at http://www.reifenetikette.ch/#reifenliste.

The 7th EAP identifies the need to rethink our approach to city design in order to reduce noise pollution in Europe by 2020. A project in Ireland has developed a Manual for Acoustic Planning and Urban Sound Design (MAP) for the city of Dublin. With the aim of encouraging a deeper level of interest in the urban sound environment by authorities and the public, MAP stimulated the introduction of urban sound installations through workshops that, as a concept, could readily be applied to other European cities. Learn more about MAP at http://map.minorarchitecture.org.

MAP, Dublin, 2014

Photo: © Sven Andersen

Noise Policy (European Commission, 1996): 'They [the noise maps] make it easy to recognise the noise exposure and thereby identify areas where action is required and other quiet areas where exposure should not increase.'

Article 8 of the END states that action plans for agglomerations with more than 250 000 inhabitants 'shall also aim to protect quiet areas against an increase in noise'. This is followed up by the requirement in Annex V to report on actions or measures that the competent authorities intend to take to preserve quiet areas. Actions may include land-use planning, systems engineering for traffic, traffic planning and noise control of sources.

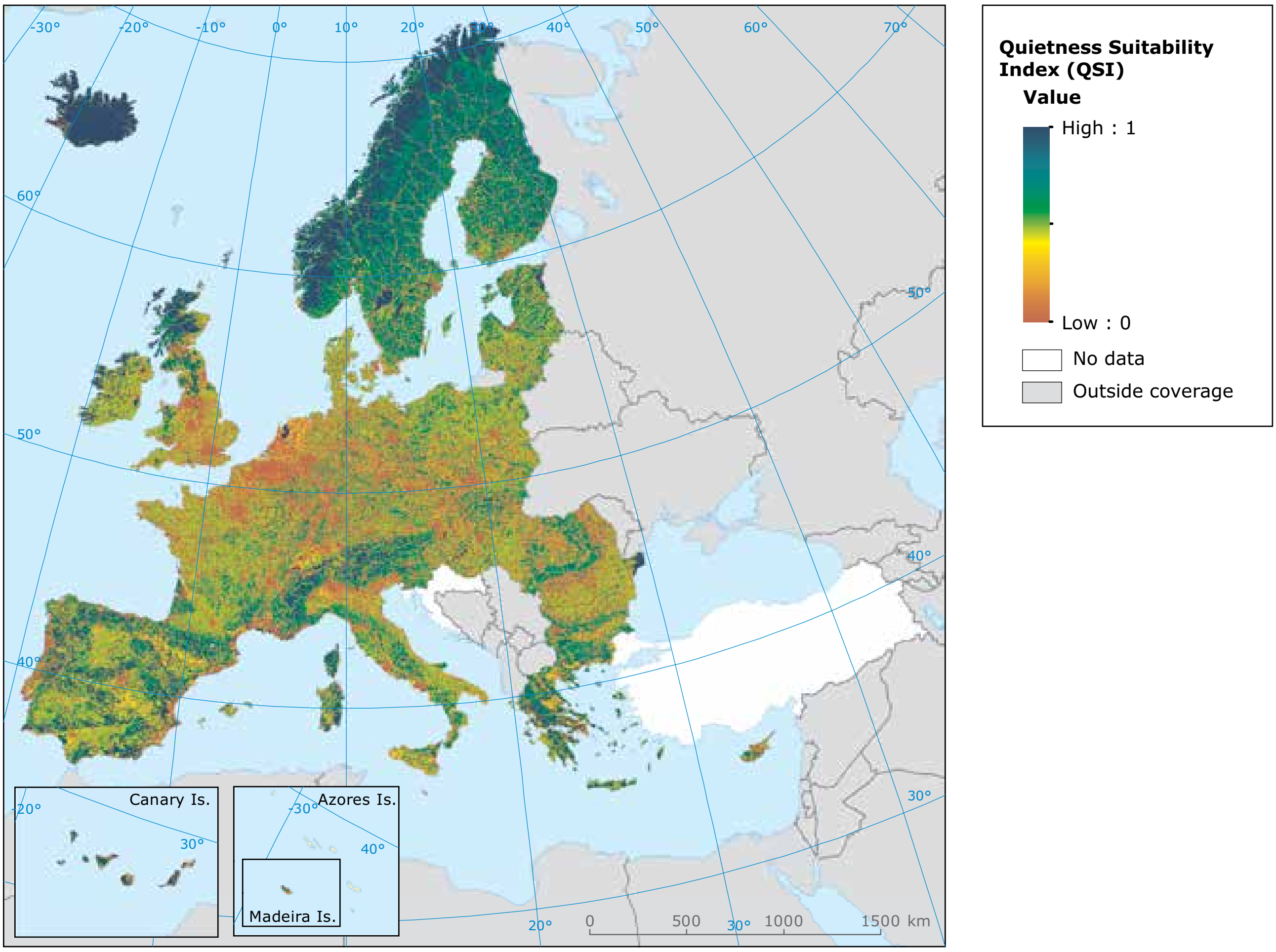
5.1.2 Quiet areas outside agglomerations

The information required by the END is focused around the major noise sources (e.g. major roads, major railways); consequently, there are large areas outside urban areas where no information is provided. Considering this constraint, the European Topic Centre for Spatial information and Analysis (ETC/SIA), together with the EEA and Expert Panel on Noise, developed a methodology to identify potential quiet areas in Europe (EEA, 2014c).

The methodology is based on the computation of a Quietness Suitability Index (QSI). This index ranges from 0 (noisy areas) to 1 (quiet areas) and noise contour maps are used as a primary source. Then, additional information is used as a proxy, such as land use and other socio-economic data, in order to have a complete European coverage.

As illustrated in Map 5.1, the noisiest areas (low QSI values) reflect very well major transport infrastructures and areas with high population density (major urban and metropolitan areas). Quiet areas are not only localised in remote areas, as can be seen near the Mediterranean coast (Greece and Spain). In terms of accessibility, it is

Map 5.1 Potential quiet areas in Europe, based upon Quietness Suitability Index (QSI)



Source: EEA, 2014.

Figure 5.2 Quiet areas by country (based on Quietness Suitability Index)

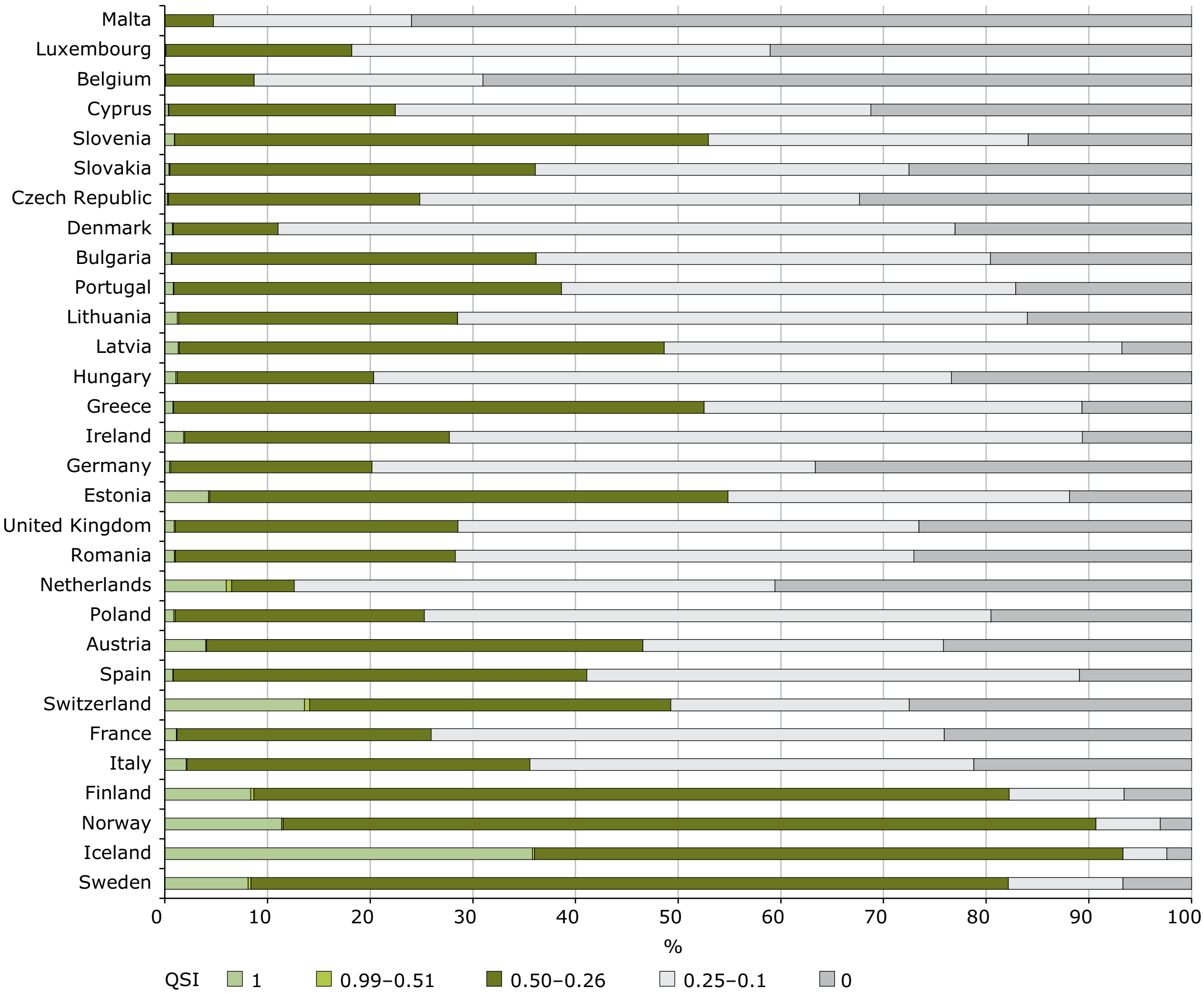


Photo: © Colin Nugent

important to identify potential quiet areas near places with high population density.

Figure 5.2 details the percentage of country area by ranges of the QSI. The QSI spans from 1 (quieter area) to 0 (noisy area).

Noisy, or relatively noisy areas (QSI < 0.5), account for more than 50 % of the land in most of the countries. The most extreme cases are found in small and densely populated countries like Belgium, Denmark, Malta and the Netherlands, where noisy areas reach around 90 % of the country. On the other side, northern countries like Finland, Iceland, Norway and Sweden have the highest share of quiet areas.

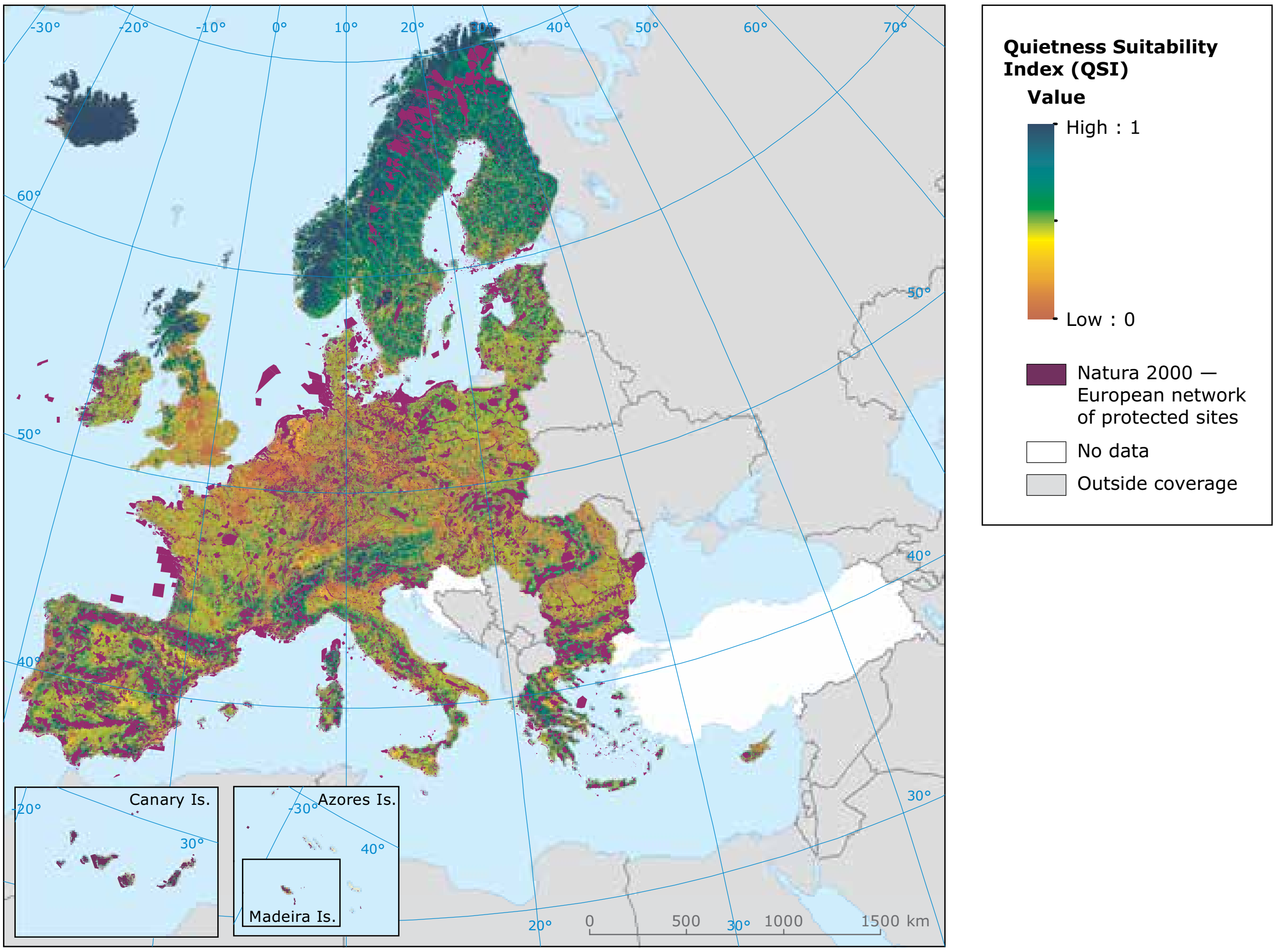
Quiet areas are also important for animals. As can be seen, the share of quiet areas inside Natura 2000 is higher compared to the share in the whole country. In particular, the Netherlands has the highest share, near 40 %. On the other hand, in small countries like Belgium, Luxembourg and Malta the share of quiet areas is very low and noisy areas represent a significant portion of the protected areas.

It should be noted that Iceland, Norway and Switzerland do not have Natura 2000 networks.

More than 50 % of quiet areas (QSI = 1) are located in Natura 2000 sites with a few exceptions (Finland and Sweden) (see Map 5.2).

A report published by the European Parliament in 2012 made recommendations for the development of a more comprehensive noise strategy, wherein the vague definition of quiet areas by the END was highlighted as leaving ample discretion for interpretation by Member States, which led to confusion and divergence in approaches to the protection of quiet areas (EU, 2012).

Map 5.2 Natura 2000 protected sites in relation to the Quietness Suitability Index



Source: EEA, 2014.

Figure 5.3 Quiet areas protected by Natura 2000 — European network of protected sites (based on Quietness Suitability Index)

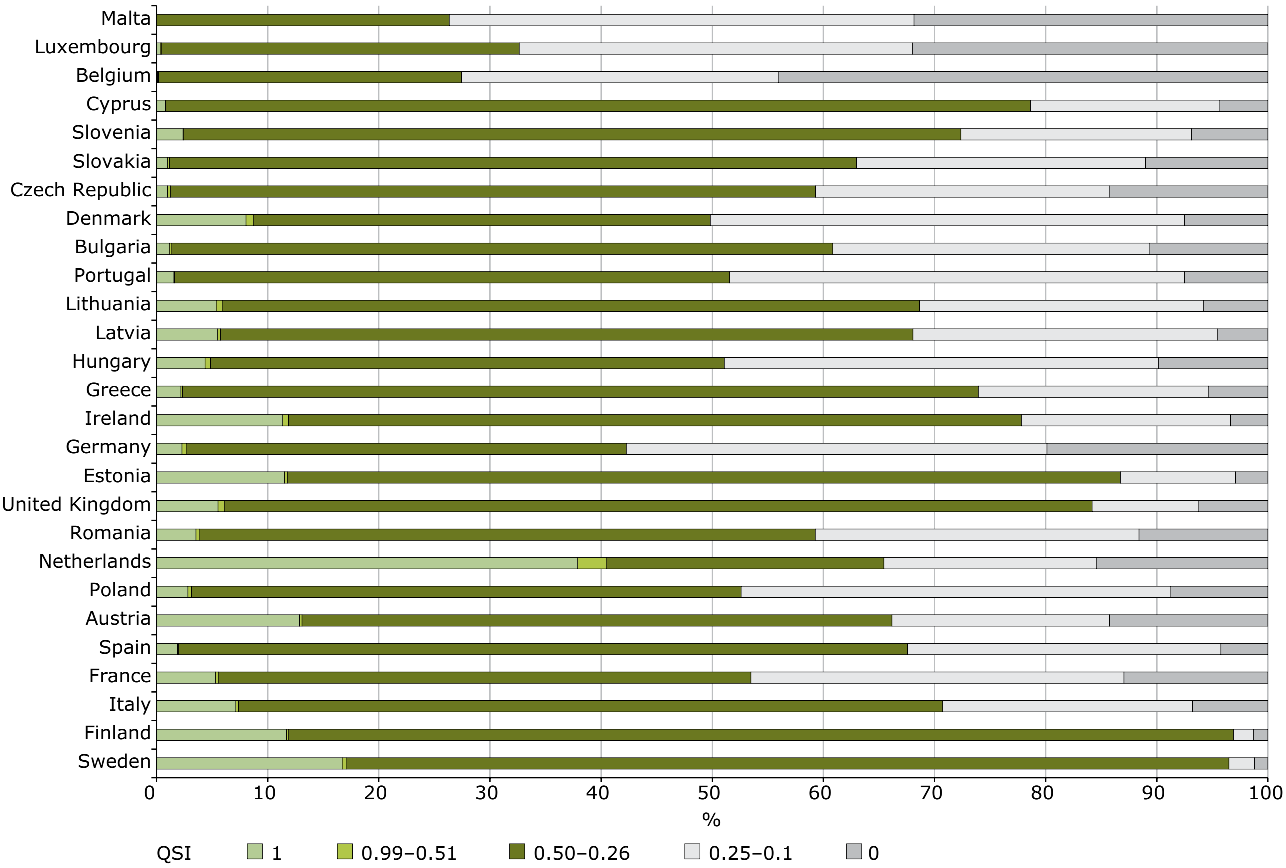
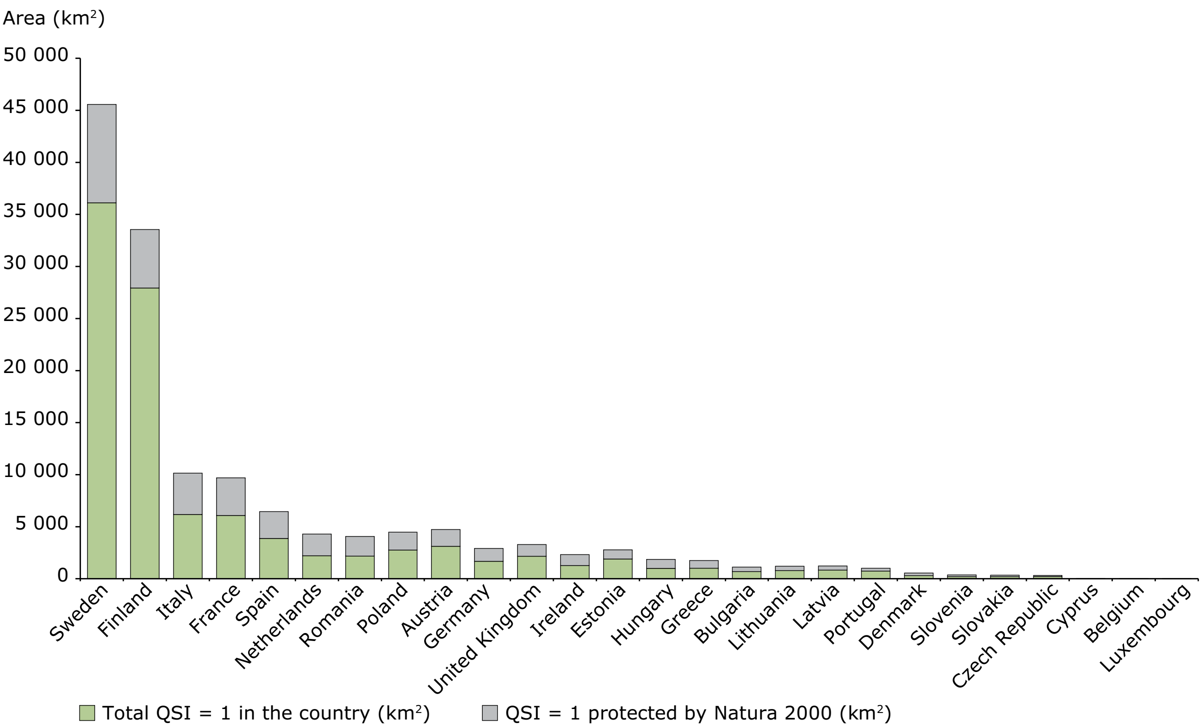


Figure 5.4 Total and protected quiet areas (QSI = 1) by country



Note: The graph highlights the total and protected by Natura 2000 quiet areas (QSI = 1) by country.

Box 5.3 EU emission limits for road vehicles

Regulation (EU) No 540/2014 of the European Parliament and of the Council on the sound level of motor vehicles and of replacement silencing systems was officially adopted on 16 April 2014 (EU, 2014).

The main elements of the regulation are:

- The old test method of the vehicle noise Directive (70/157/EEC) will be replaced by a new test method recognised internationally and better reflecting present driving behaviour. This new test method has already been used in the EU for monitoring purposes for 3 years. It was developed under the auspices of the United Nations Economic Commission for Europe (UNECE).
- The limit values will be lowered in two steps of each 2 dB(A) for passenger cars, buses and light trucks; for heavy duty vehicles the reduction will be 1 dB(A) in the first step and 2 dB(A) in the second step. The first step is foreseen to apply 7 years after the date of publication of the proposal in the Official Journal of the European Union (OJ); the second step shall follow after a further 4 years. The proposed reduction would apply to the noise values resulting from the application of the new test method.
- Additional sound emission provisions (ASEP) will be included in the type-approval procedure and the existing derogations for certain vehicle types will be revised. ASEP are preventive requirements intended to cover driving conditions of the vehicle in real traffic outside the type-approval driving cycle. These driving conditions are environmentally relevant and it needs to be ensured that the sound emission of a vehicle under street driving conditions does not differ significantly from the vehicle tested.
- A specific annex on the minimum noise ('Approaching Vehicle Audible Systems') of electric and hybrid electric vehicles is proposed to be added. These requirements shall ensure that only adequate sound-generating devices are used and it shall lead to a harmonisation of the applied technology. The fitting was made mandatory by the legislator for electric/hybrid vehicles (after 5 years/publication).
- To foster competition, the legislator also introduced some requirements on the noise labelling at dealerships. 'Manufacturers shall endeavour to ensure that the sound level of each vehicle is displayed at the point of sale.' The Commission will have to carry out an impact assessment on further developing those requirements.

The provisions of the directive are expected to influence levels of environmental noise from road traffic in Europe around 13 years after its introduction — i.e. by mid-2027 (European Commission, 2011).

By contrast, an impact assessment of the proposed limits as conducted by the German Federal Environment Agency concluded that the new vehicle emission limits would have little or no impact upon reducing levels of environmental noise in that country. The reasons were identified as including the long lead-in period, disregard for the dominance of tyre noise, requirements to increase sound levels from otherwise quiet vehicles and lack of effective test method for the limits (UBA, 2012).

The EEA has published a digest of good practice in relation to the identification and management of quiet areas, which is available for download at http://www.eea.europa.eu/publications/good-practice-guide-on-quiet-areas.

6 Conclusions

As this report marks the first European-scale assessment of noise, it is not possible to draw firm conclusions about past trends concerning the state of Europe's acoustic environment. What we do know is that noise is one of the most pervasive pollutants in Europe and that drivers such as economic growth, expanding urbanisation, more extensive transport networks and increased industrial output will present challenges to protecting the quality of the European soundscape. Increased pressures impact upon our ability to protect our own health and the health of sensitive populations such as the young, the immobile and those living in deprived areas, which may well be at most risk from the adverse health effects associated with noise.

The health of our ecosystems is also at risk. The noise maps of Europe reveal graphically how the extent of even relatively moderate levels of noise such as 55 dB L_{den} are consuming more and more territorial area outside of urban areas and directly threatening valuable habitats and species that are particularly susceptible to noise.

It is clear from END data and citizen ratings that noise from road traffic is the most dominant threat, both due to its geographical extent and by the numbers of people it affects. In addition, while airports do not affect a wide geographical area, the effects of aircraft noise extend beyond the damage to health of those people living nearby airports. It also directly impacts the ability of younger generations to concentrate and learn in schools affected by aircraft flight paths. Although railway noise does not have the same high numbers of exposure that road traffic reaches, the numbers of people affected remain significant. In cities, it would appear from END data reports that sea ports and industrial sites are not affecting a very great number — less than half a million people, compared to the other sources — yet citizen ratings of noise in Europe indicate that industrial noise is the second most dominant source affecting our environment. Further work may be required to assess the extent of industrial noise assessments reported to EEA.

The greatest challenge to assessing Europe's noise environment lies mainly with data completeness. In terms of END data, we only have 44 % of the picture for some sources. This is entirely due to late reporting by countries. Even if there have been some limited improvements, this situation needs to be addressed urgently if the knowledge base for the further development of noise policy in Europe is to be strengthened. Data from mobile applications also offers an opportunity to learn more about the sources of noise affecting people living outside the scope of the END or distant from measurement stations.

Noise contour map data provide an opportunity to expand spatial analysis of our environment to also include the potential impact of noise upon biodiversity loss and habitat fragmentation. The impact of noise in this regard undoubtedly needs better quantification.

Data accessibility at European level is the cornerstone of providing a Shared Environmental Information System (SEIS) (European Commission, 2008). SEIS builds upon a set of data management principles that improve access to data sets, prevent unnecessary duplication of data collection and allow decentralised quality control. In this context, the synergy between different pollutants is marked. On every level, from defining agglomerations to implementing action plans, the assessments for air and noise pollution exhibit similarities. These synergies require further exploration to achieve a more integrated solution to ensuring health and well-being of urban populations.

Other challenges are more immediate. Road traffic noise is today the second worst environmental pollutant in Europe with at least 1 million healthy life years lost each year according to the WHO in 2011. Even the incomplete 2012 noise mapping data shows that there are at least 10 000 cases of premature death in Europe and at least 43 000 cases of hospitalisation each year, that almost 20 million people suffer annoyance and a further 8 million suffer sleep disturbance. Due to the incomplete reporting, these numbers are likely significantly underestimated, potentially by more than a factor of two, meaning overall impacts upon society are expected to be much greater.

Moreover, assessments cannot yet be made to compare noise levels in Europe with WHO recommended levels for night time exposure, as reporting of this information by countries is not mandatory. The EEA requests this data in the ENDRM, but as yet only a few countries have responded.

Aside from the impacts upon human health, there needs to be more concerted European and country-level effort in relation to assessing the economic impacts of inaction on noise pollution. While member countries are encouraged to implement action plans against noise, action at source is often a more effective measure. Recent revision of vehicle emission limits is an important measure, but the timescales for implementation may render the action inconsequential. Similarly, labelling of car tyres can only succeed if the consumer is informed and/or incentivised to act upon the information provided by the label. It can be noted that the same regulation on vehicle noise emissions also requires the increase of sound levels from electric vehicles.

Regarding industrial noise, there are relevant provisions in European legislation but it is not yet possible to assess the effectiveness of those provisions. Again, apparent under-implementation of the END, and the wide data gaps that exist for sea port noise assessments in particular, is a significant obstacle.

Finally, it should be noted that action need not always focus upon the areas of highest decibel levels or the so-called 'hot-spots' as identified by noise contour mapping. Even a reduction of 10 dB can present little tangible benefit to inhabitants of an urban area experiencing an L_{den} of 75 dB or more. Attention should also be paid to those areas not appearing above the threshold for actions — the areas where the acoustic environment is good. Such a two-fold approach to reducing environmental noise and protecting relatively quiet areas offers a strategy to protect our health and preserve Europe's natural soundscape before each is further degraded.

References

Babisch, W. 2002, The Noise/Stress Concept, Risk Assessments and Research Needs, Noise Health, 4(16), 1–11.

Babisch, W. and Van Kamp, I., 2009, 'Exposure-response relationship of the association between aircraft noise and the risk of hypertension', *Noise and Health*, 11(44) 161–168.

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S. and Stansfeld, S., 2014, 'Auditory and non-auditory effects of noise on health', *The Lancet*, 383(9925) 1 325–1 332.

Clark, C., Martin, R., Van Kempen, E., Alfred, T., Head, J., Davies, H.W., Haines, M.M., Barrio, I.L., Matheson, M., Stansfeld, S. A., 2006, 'Exposure-effect relations between aircraft and road traffic noise exposure at school and reading comprehension: The RANCH project', *American Journal of Epidemiology*, 163(1) 27–37.

Correia, A.W., Junenette, L., Jonathan, I., Melly, S. and Dominici, F., 2013, 'Residential exposure to aircraft noise and hospital admissions for cardiovascular diseases: Multi-airport retrospective study', *BMJ* (online), 347(7928) Art. no f5561.

Cueto, J.L. and Licitra, G., 2013, 'Geographic information system tools for noise mapping', in: Licitra, G. (ed.), *Noise Mapping in the EU: Models and Procedures*, CRC Press, London.

De Kluizenaar, Y., Van Lenthe, F. J., Visschedijk, A.J.H., Zandveld, P.Y.J., Miedema, H.M.E. and Mackenbach, J. P., 2013, 'Road traffic noise, air pollution components and cardiovascular events', *Noise and Health*, 15(67) 388–397.

Defra, 2008, *An Economic Valuation of Noise Pollution — developing a tool for policy appraisal*, first report of the Interdepartmental Group on Costs and Benefits, Noise subject group.

Defra, 2011, *The Economic Value of Quiet Areas*, Final report prepared by URS/Scott Wilson.

Dutilleux, G., 2012, *Anthropogenic outdoor sound and wildlife: it's not just bioacoustics!*, Proceedings Acoustics, 2301–2306, Nantes (hal.archives-ouvertes.fr/docs/00/81/07/95/PDF/hal-00810795.pdf) accessed 18 October 2014.

EEA, 2010, *Good practice guide on noise exposure and potential health effects*, EEA Technical report No 11/2010, European Environment Agency (http://www.eea.europa.eu/publications/good-practice-guide-on-noise).

EEA, 2012, *Electronic Noise Data Reporting Mechanism – a handbook for delivery of data in accordance with Directive 2002/49/EC*, EEA Technical report No 9/2012, European Environment Agency (http://www.eea.europa.eu/publications/noise-handbook).

EEA, 2013, *A closer look at urban transport, TERM 2013: transport indicators tracking progress towards environmental targets in Europe*, EEA Report No 11/2013, European Environment Agency (http://www.eea.europa.eu/publications/term-2013).

EEA, 2014a, *Analysing and managing urban growth*, European Environment Agency (http://www.eea.europa.eu/articles/analysing-and-managing-urban-growth) accessed 10 July 2014.

EEA, 2014b, NoiseWatch database, European Environment Agency (http://discomap.eea.europa.eu/map/NoiseWatch) accessed 08 December 2014.

EEA, 2014c, *Good practice guide on quiet areas*, EEA Technical report No 4/2014 European Environment Agency (http://www.eea.europa.eu/publications/good-practice-guide-on-quiet-areas).

ERF, 2004, *Road traffic noise: The Road Sector's Perspective*, European Union Road Federation, . (http://www.irfnet.ch/files-upload/pdf-files/2661_erf_position_on_noise.pdf) accessed 28 November 2014.

EU, 2002a, Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise (OJ L 129, 18.7.2002, p. 12–25) (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0049&from=EN) accessed 18 October 2014.

EU, 2002b, Directive 2002/30/EC of the European Parliament and of the Council of 26 March 2002 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Community airports (OJ L 85, 28.3.2002, p. 40–46) (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0030&from=EN) accessed 18 October 2014.

EU, 2010, Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (OJ L 334, 17.12.2010, p. 17–119). (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=EN) accessed 18 October 2014.

EU, 2013, Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' (OJ L 354, 20.12.2013, p. 171–200) (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013D1386) accessed 18 October 2014.

European Commission, 1996, Green Paper on Future Noise Policy, EC.

European Commission, 2002, *Position paper on dose response relationships between transportation noise and annoyance*, EU's Future Noise Policy, Working Group 2 (WG2) – Dose/Effect, Luxembourg (http://ec.europa.eu/environment/noise/pdf/noise_expert_network.pdf) accessed 28 November 2014.

European Commission, 2003, Position paper on the valuation of noise (http://ec.europa.eu/environment/noise/pdf/valuatio_final_12_2003.pdf) accessed 28 November 2014.

European Commission, 2004, *Position paper on dose-effect relationships for night time noise*, European Commission Working Group on Health and Socio-Economic Aspects, Luxembourg (http://ec.europa.eu/environment/noise/pdf/positionpaper.pdf) accessed 28 November 2014.

European Commission, 2008, *Towards a Shared Environmental Information System (SEIS)*, Communication from the Commission to the Council, The European Parliament, the European Economic and Social Committee and the Committee of the Regions, Brussels, 1.2.2008, COM (2008) 46 Final.

European Commission, 2011, *Report to the European Parliament and the Council on the implementation of the Environmental Noise Directive in accordance with Article 11 of Directive 2002/49/EC (COM(2011) 321 final of 1 June 2011* (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0321:FIN:EN:PDF) accessed 18 October 2014.

European Commission, 2014, 'The Environmental Noise Directive (2002/49/EC) — General aims and principles' (http://ec.europa.eu/environment/noise/directive.htm) accessed 18 October 2014.

EU, 2012, *Towards a comprehensive noise strategy*, Directorate-General for Internal Policies, Policy Department A: Economic and Scientific Policy.

Eurostat, 2010, 'Eurostat Statistical Database', Eurostat, Luxembourg (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database) accessed 17 February 2014.

Extrium, 2013, Technical note to the European Environment Agency on forecasting ENDRM DF4_8 data to 2020, 2030 and 2050, 29 November 2013 (http://forum.eionet.europa.eu/nrc-noise/library/noise-report-2014).

Floud, S., Blangiardo, M., Clark, C., De Hoogh, K., Babisch, W., Houthuijs, D., Swart, W., Pershagen, G., Katsouyanni, K., Velonakis, M., Vigna-Taglianti, F., Cadum, E. and Hansell, A. L., 2013, 'Exposure to aircraft and road traffic noise and associations with heart disease and stroke in six European countries: A cross-sectional study', *Environmental Health*, 12(1) Art. no 89.

FOEN, 2010, *External Costs and Benefits of Transport in Switzerland 2010*, Federal Office for the Environment, Switzerland (http://www.are.admin.ch/themen/verkehr/00252/00472/index.html?lang=en) accessed 28 November 2014

Hansell, A.L., Blangiardo, M., Fortunato, L., Floud, S., De Hoogh, K., Fecht, D., Ghosh, R.E., Laszlo, H.E., Pearson, C., Beale, L., Beevers, S., Gulliver, J., Best, N., Richardson, S. and Elliott, P., 2013, 'Aircraft noise and cardiovascular disease near Heathrow airport in London: Small area study', *BMJ* (online), 347(7928) .

Huss, A., Spoerri, A., Egger, M. and Röösli, M., 2010, 'Aircraft noise, air pollution, and mortality from myocardial infarction', *Epidemiology*, 21(6) 829–836.

Hygge, S., Evans, G.W., Bullinger, M., 2002, 'A prospective study of some effects of aircraft noise on cognitive performance in school children' *Psychological Science*, , 13:469–474.

ISO, 2003, 'ISO 1996-1:2003 Acoustics – Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment procedures', International Organization for Standardization (http://www.iso.org/iso/catalogue_detail?csnumber=28633) accessed 28 November 2014.

Jarup, L., Dudley, M-L., Babisch, W., Houthuijs, D., Swart, W., Pershagen, G., Bluhm, G., Katsouyanni, K., Velonakis, M., Cadum, E. and Vigna-Taglianti, F., 2005, 'Hypertension and Exposure to Noise near Airports (HYENA): Study design and noise exposure assessment', *Environmental Health Perspectives*, 113(11) 1 473–1 478.

Janssen, S.A. and Vos, H., 2009, *A comparison of recent surveys to aircraft noise exposure-response relationships*, TNO report TNO-034-DTM-2009-01799, Delft.

JRC, 2014, *Common Noise Assessment Methods in Europe (CNOSSOS-EU)*, European Commission Joint Research Centre (http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26390/1/cnossos-eu%20jrc%20reference%20report_final_on%20line%20version_10%20august%202012.pdf) accessed 31 October 2014.

Kephalopoulos, S. and Paviotti, M., 2013, 'Noise maps from different national assessment methods: Differences, uncertainties, and needs for harmonization', in: Licitra, G. (ed.), *Noise Mapping in the EU: Models and Procedures*, CRC Press, London.

Koelega, H.S. (ed.) 1987, Environmental Annoyance: characterisation, measurement and control, Amsterdam: Elsevier.

Licitra, G. and Ascari, E., 2013, 'The Good Practice Guide, Version 2', in: Licitra, G. (ed.), *Noise Mapping in the EU: Models and Procedures*, CRC Press, London.

Miedema, H.M.E. and Oudshoorn, C.G.M., 2001, 'Annoyance from transportation noise: Relationships with exposure metrics DNL and DENL and their confidence intervals', *Environmental Health Perspectives*, 109(4) 409–416.

Miedema, H.M.E. and Vos, H., 2004, 'Noise annoyance from stationary sources: Relationships with exposure metric day-evening-night level (DENL) and their confidence intervals', *Journal of the Acoustical Society of America*, 116(1) 334–343.

Miedema H.M.E. and Vos, H., 2007, 'Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies', *Behavioral Sleep Medicine*, 5(1) 1–20.

Miljøstyrelsen (Denmark), 2013, *Miljøråd — En samfundsøkonomisk analyse*, Miljøprojekt nr. 1478, 2013.

Naturvårdsverket, 2014, *Kartläggning av antalet överexponerade för buller*, Uppdragsnummer 3581062000.

Navrud, S., 2002, The State of the Art on Economic Valuation of Noise. Final report to the European Commission, DG Environment, 14 April 2002.

Pearsons, K.S. 1998, *Awakening and Motility Effects of Aircraft Noise, Noise Effects 1998*, Vol. 2, pp. 427–432, Sydney: PTY.

Sørensen, M., Hvidberg, M., Andersen, Z.J., Nordsborg, R.B., Lillelund, K. G., Jakobsen, J., Tjønneland, A., Overvad, K. and Raaschou-Nielsen, O., 2011, 'Road traffic noise and stroke: A prospective cohort study', *European Heart Journal*, 32(6) 737–744.

Sørensen, M., Andersen, Z.J., Nordsborg, R. B., Becker, T., Tjønneland, A., Overvad, K. and Raaschou-Nielsen, O., 2013, 'Long-term exposure to road traffic noise and incident diabetes: A cohort study', *Environmental Health Perspectives*, 121(2) 217–222.

Sørensen, M., Ketzel, M., Overvad, K., Tjønneland, A. and Raaschou-Nielsen, O., 2014, 'Exposure to road traffic and railway noise and postmenopausal breast cancer: A cohort study', *International Journal of Cancer*, 134(11) 2 691–2 698.

Stansfeld, S.A., Berglund, B., Clark, C., Lopez-Barrio, I., Fischer, P., Öhrström, E., Haines, M. M., Head, J., Hygge, S., Van Kamp, I., Berry, B.F., 2005, 'Aircraft and road traffic noise and children's cognition and health: A cross-national study', *Lancet*, 365(9475) 1 942–1 949.

Stansfeld, S. and Clark, C., 2011, 'Outcomes of the European network on noise and health (ENNAH)', *40th International Congress and Exposition on Noise Control Engineering*, Proceedings of INTER-NOISE 2011, Osaka, pp. 25–29.

T&E, 2008, *Can you hear us? Why it is finally time for the EU to tackle the problem of noise from road and rail traffic*, European Federation for Transport and Environment, T&E 08/1, Brussels (http://www.transportenvironment.org/sites/te/files/media/2008-02_traffic_noise_can_you_hear_us.pdf) accessed 18 November 2014.

UBA, 2012, *Proposal for a Limit Value Reduction Scenario for Road Vehicles compatible with the German National Traffic Noise Prevention* (http://www.uba.de/uba-info-medien-e/4270.html) accessed 11 October 2014.

UNECE, 1998, 'UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters', United Nations Economic Commission for Europe (http://www.unece.org/env/pp/introduction.html) accessed 18 October, 2014.

Van Blokland, G. and Peeters, B. 2009, *Modelling the noise emission of road vehicles and results of recent experiments*, Internoise 2009, Ottawa, Canada, 23–26 August 2009 (https://www.mp.nl/sites/all/files/publicaties/in09_895.pdf) accessed 28 November 2014.

Van Kempen, E.E.M.M., 2008, *Transportation noise exposure and children's health and cognition*, Thesis, Utrecht University, Utrecht (http://dspace.library.uu.nl/handle/1874/25891) accessed 28 November 2014.

Van Kempen, E. and Babisch, W., 2012, 'The quantitative relationship between road traffic noise and hypertension: A meta-analysis', *Journal of Hypertension*, 30(6) 1 075–1 086.

Vienneau, D., Perez, L., Schindler, C., Probst-Hensch, N. and Röösli, M., 2013, 'The relationship between traffic noise exposure and ischemic heart disease: a meta-analysis', *42nd International Congress and Exposition on Noise Control Engineering*, Proceedings of INTER-NOISE 2013, Innsbruck, pp. 5 070–5 076.

WHO, 1972, Technical report series 506, Geneva: World Health Organization.

WHO, 1999, *Guidelines for Community Noise*, Berglund, B., Lindvall, T. and Schwela, D.H. (eds), World Health Organization, Geneva (http://www.who.int/docstore/peh/noise/guidelines2.html) accessed 28 November 2014.

WHO, 2009, *Night noise guidelines for Europe*, World Health Organization Regional Office for Europe (http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf?ua=1) accessed 18 October 2014.

WHO, 2011, *Burden of disease from environmental noise. Quantification of healthy life years lost in Europe*, World Health Organization Regional Office for Europe, Copenhagen (http://www.who.int/entity/quantifying_ehimpacts/publications/e94888.pdf?ua=1) accessed 18 October 2014.

Annex 1 Examples of noise-related legislation in the European Union

Directive 89/629/EEC of 4th December 1989 on the limitation of noise emission form civil subsonic jet aeroplanes, 1989.

Directive 2006/93/EC on the regulation of the operation of aeroplanes covered by the Convention on International Civil Aviation, 2006.

Regulation 216/2008/EC on common rules in the field of civil aviation, 2008.

Communication on air transport and the environment, 1999.

Directive 96/48/EC on the interoperability of the trans-European high speed rail system, 1996.

Directive 97/24/EC on certain components and characteristics of two or three wheel motor vehicles, 1997.

Directive 2001/43/EC amending Council Directive 92/23/EEC relating to tyres for motor vehicles and their trailers and to their fitting, 2001.

Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment, 1985.

Directive 2000/14/EC on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors, 2001.

Directive 2001/16/EC on the interoperability of the trans-European conventional rail system, 2001.

Commission Decision 2002/735/EC concerning the technical specification for interoperability relating to the Rolling stock subsystem of the trans-European high speed rail system referred to in Article 6(1) of Directive 96/48/EC.

Commission Decision 2002/732/EC relating to technical specification for interoperability relating to high speed railway infrastructures, 2002.

Commission Decision of 29 April 2004 specifying the basic parameters of the Noise, Freight Wagons and Telematic applications for freight, Technical specifications for interoperability referred to in Directive 2001/16/EC, 2004.

Directive 92/23/EEC of the European Parliament and of the Council of 31 March 1992 relating to tyres for motor vehicles and their trailers and to their fitting, 1992.

Directive 2001/43/EC of the European Parliament and of the Council of amendment of 92/23/EC relating to tyre noise emission.

Directive 2003/44/EC of the European Parliament and of the Council of 16 June 2003 amending Directive 94/25/EC on the approximation of the laws, regulations and administrative provisions of the Member States relating to recreational craft, 2003

Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (Recast), 2006.

Regulation (EC) No 661/2009 of the European Parliament and of the Council of 13 July 2009 concerning type approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefore, 2009.

Regulation (EC) No 1222/2009 of the European Parliament and of the Council of 25 November 2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters, 2009.

Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast), 2010.

Regulation (EU) No 540/2014 of the European Parliament and of the Council of 16 April 2014 on the sound level of motor vehicles and of

replacement silencing systems, and amending Directive 2007/46/EC and repealing Directive 70/157/EEC, 2014.

Regulation (EU) No 598/2014 of the European parliament and of the Council of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC, 2014.

Annex 2 Example of data gap-filling methodology applied to agglomeration road data

Option 1 – Use ENDRM DF4_8 results as reported and contained in the NOISE database.

- Method applied for 307 of the 472 listed agglomerations.

Option 2 – Where results are not reported for DF4_8 (as indicated by the NOISE database), derive results for the phase 2 agglomeration, from the phase 1 results for the same agglomeration (if available) adjusted to reflect any updates to the agglomeration population in phase 2.

- Method applied for 44 of the 472 listed agglomerations.

Option 3 – Where results are not reported for DF4_8 (as indicated by the NOISE database), derive results for the phase 2 agglomeration, from the phase 2 average results reported for the same country (where available) adjusted to reflect any updates to the agglomeration population in phase 2.

- Method applied for 81 of the 472 listed agglomerations.

Option 4 – Where results are not reported for DF4_8 (as indicated by the NOISE database), derive results for the phase 2 agglomeration, from the phase 1 average results reported for the same country (where available) adjusted to reflect any updates to the agglomeration population in phase 2.

- Method applied for 28 of the 472 listed agglomerations.

Option 5 – Where results are not reported for DF4_8 (as indicated by the NOISE database), derive results for the phase 2 agglomeration, from the phase 2 NOISE database EEA-wide average results, adjusted to reflect any updates to the agglomeration population in phase 2.

Exclusions – Where results are not reported for phase 2 and no information on the population of the agglomeration has been provided (i.e. DF1_5), it was not possible to provide a quick forecast of the estimated exposure, and therefore the agglomeration has been excluded from this analysis.

- 8 of the 472 listed agglomerations (in Greece and Turkey) have been excluded from this analysis and no results have been incorporated from Croatia or Turkey, as no information has been reported in DF1_5.

The technical note on gap filling methodological approach may be accessed in full at: http://forum.eionet.europa.eu/nrc-noise/library/noise-report-2014

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