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Road traffic noise exposure in Europe in 2012 based on END data

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ABSTRACT

Based on the Environmental Noise Directive (END), noise mapping figures on road traffic noise exposure should encourage the European National Road Authorities to describe noise reducing measures in END action plans. The END figures also provide a basis for developing Community measures to reduce noise emitted by the major sources like vehicles and tyres. In 2007 and 2012, END noise mapping provided a lot of information. These END data is used to estimate road traffic noise exposure in the EU-30 countries in 2012. However, the END data is far from complete. Workarounds are necessary to fill the gaps and to improve the quality of the estimations. The outcome of the END data quality assessment provides figures on (major) road traffic noise exposure and noise annoyance in Europe in 2012. For the National Road Authorities cooperating in the Conference of European Directors of Roads (CEDR), these figures are useful in optimizing the practical application of noise reducing pavements and noise barriers in terms of costs and benefits. Secondly, these figures demonstrate the potential noise exposure and noise annoyance reduction of implementing noise reducing measures on a European scale.

Keywords: Road traffic noise, Environmental Noise Directive, Noise mapping
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1. INTRODUCTION

In Europe the National Road Authorities (NRAs) form the Conference of European Directors of Roads (CEDR). The purpose of this co-operation at European level is to facilitate the exchange of experience and information and to analyse and discuss all road-related issues such as road traffic noise. In the period 2013–2017, the CEDR Task Group Road Noise collated and dispersed information on the results of recent innovative road noise research within CEDR member states. Implementing the results of road traffic noise research should improve road traffic noise quality in close proximity to road infrastructure and reduce costs in planning, building and maintaining road infrastructure.
Implementing the results of road noise research in the next years, improves the road traffic noise quality in terms of reduction of road noise exposure and annoyance. To estimate the effect of implementing these results, there is a need for road noise exposure data at a European scale. Due to different noise-reducing characteristics of these results, it is important to differentiate between major roads and non-major roads and inside and outside agglomerations. This would improve the effectiveness and outcome of implementing the road noise research results. However, the availability of data to enable these calculations is limited. The data provided by the European countries within the framework of the Environmental Noise Directive (END), is the only traffic noise dataset on a European level; therefore, the END data is used to achieve the following main goals:

- calculate road traffic noise exposure and annoyance along European roads;
- estimate the effect of implementing results of road noise research on noise exposure and annoyance along European roads.

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2. END DATA ON NOISE MAPPING

2.1 General information

In June 2002, Directive 2002/49 relating to the assessment and management of environmental noise, was adopted by the European Parliament and the Council (1). One of the underlying principles of the END is to monitor the environmental noise problem, by requiring competent authorities in member states to draw up strategic noise maps for major roads, railways, airports and agglomerations. These maps also give information on the number of people exposed to (road traffic) noise in the European Union (EU) countries. The END sets out a cyclical process where key actions such as strategic noise mapping must be repeated every five years. The first round of noise mapping was delivered by the EU countries in 2007 and the second round was delivered in 2012.

For roads, the EU countries delivered data about noise exposure from traffic on all roads (major and non-major) inside agglomerations and from traffic on major roads outside agglomerations and including agglomerations. The END data on population exposure to road traffic noise is available on the NOISE (Noise Observation and Information Service for Europe) website. NOISE is maintained by the European Environment Agency (EEA) and the European Topic Centre for Air Pollution and Climate Change Mitigation (ETC-ACM) on behalf of the European Commission. END data can be downloaded at: http://forum.eionet.europa.eu/etc-sia-consortium/library/noise_database/index_html. The most recent update for 2007 data was made on 11th February 2016. In relation to the second round noise mapping in 2012, the most recent submission of 2012 data was made on 24th November 2015.

A review was undertaken of data available from the NOISE website. This review determined that more than 30 countries reported data for second round 2012 END noise mapping. Whilst Iceland, Liechtenstein, Norway, Switzerland and Turkey are not EU member states, these countries prepared strategic noise maps and submitted data on a voluntary basis. The following countries did not provide data: Croatia, Liechtenstein, Macedonia, Montenegro and Turkey. This report is based on END data on noise exposure from road traffic, provided by 30 European countries (EU-30).

2.2 Length of roads in Europe

In the first round of END noise mapping in 2007, major roads are defined as having more than six million vehicle passages a year (more than 16 500 vehicles per day). In the second round of END noise mapping in 2012 and for all subsequent rounds major roads have more than three million vehicle passages a year (more than 8 200 vehicles per day). However, END major roads are just a small part of all roads in the EU-30 territory, similar to how motorways are a small part of the END major roads (see Table 1).

Table 1 – The total length of roads in Europe

	length of roads in EU-30 territory in 2012 (in km)
motorways *	74 000
END major roads	211 000
all roads **/***	5 690 000

* sources: Eurostat and ERF (2)

** according to de Roo et al. (3), the total road length in EU-27 in 2008/2009 is 5 030 000 km

*** source: ERF (2)

2.3 Quality Assessment END data

2.3.1 Roads inside END agglomerations in 2012

According to the 2012 END data reported in November 2015, there are 482 END agglomerations with more than 100 000 inhabitants in the EU-30 countries. In relation to these 482 agglomerations, the following is noted:

- 379 agglomerations reported their data (79 %). Therefore, about 20 % of data for agglomerations has not been reported yet. There is road noise data missing for many agglomerations in several EU countries, in particular Belgium, Cyprus, France, Greece, Hungary, Italy, Latvia, Portugal,

Romania, Slovenia, Slovakia and Spain.

- In several EU countries, specifically Bulgaria, France, Germany, Italy and United Kingdom, the reported 2012 data shows percentages of people in agglomerations exposed to road noise levels of 55 dB L_{den} or more that are either greater than 80 % or less than 20 %. For these 111 agglomerations the reported 2012 data is excluded from the calculations due to these data outliers.

To estimate the 2012 agglomeration data on road traffic exposure, workarounds are necessary to fill the gaps:

- use END 2012 results reported and uploaded in the NOISE database on 24th November 2015 (as on 4th March 2016).
- exclude END 2012 results in the NOISE database in case percentages of people in agglomerations exposed to road traffic noise levels of 55 dB L_{den} or more exceed 80 % or are less than 20 %;
- use the proportionate distribution of people exposed to road traffic noise in 2007 for the same agglomeration, adjusted to reflect any updates to the agglomeration population in 2012;
- use the average proportionate distribution of people in agglomerations exposed to road traffic noise in 2012 in this EU-30 country, adjusted to reflect any updates to the agglomeration population in 2012;
- use the average proportionate distribution of people in agglomerations exposed to road traffic noise in 2012 in the EU-30 countries, adjusted to reflect any updates to the agglomeration population in 2012.

The workarounds used in this report correspond to the gap-filling analysis used by Extrium (4) and EEA (5). However, the following important differences exist:

- In this paper, the original 2012 END dataset dates from 24th November 2015, whereas the END dataset used by Extrium (4) and EAA (5) dates from 28th August 2013. Since August 2013, new END data deliveries enhanced and improved the basic 2012 END datasets.
- In this paper, the quality assessment excluded outliers before the workarounds started. Workarounds are used to estimate noise exposure in these agglomerations. This approach gives figures for all END agglomerations, in contrast to the Extrium (4) and EEA (5) analysis.

2.3.2 Major roads outside END agglomerations in 2012

Changing the first round limit for traffic on major roads from more than six million vehicle passages a year into the second round limit of three million vehicle passages a year, resulted in an increase in the length of major roads outside agglomerations. There is, however, a second factor influencing the development of the number of people living along major roads outside agglomerations. What used to be a major road outside an agglomeration in 2007, can be a major road inside an agglomeration in 2012. The following has been noted:

- 24 EU-30 countries reported their major road data (80 %). Therefore, the 2012 data for major roads outside agglomerations is incomplete. Major road noise data is missing for several EU countries: Cyprus, Czech Republic, Estonia, Greece, Hungary and Slovenia.
- In two EU countries, Portugal and Romania, the reported 2012 data show the number of people outside agglomerations exposed to major road traffic noise levels of 55 dB L_{den} or more that are hard to believe. For these two countries, the reported 2012 data is excluded from the calculations.
- For France, there is only information for major roads with more than three million and less than six million vehicle passages per year outside agglomerations.

To estimate the 2012 data on major road traffic exposure outside agglomerations, workarounds are necessary to fill the gaps:

- use END 2012 results reported and uploaded in the NOISE database on 24th November 2015 (as on 4th March 2016);
- exclude END 2012 results in the NOISE database in case the number of people living along major roads outside agglomerations is remarkably low;
- use the average proportionate distribution of people outside agglomerations exposed to road traffic noise from major roads in 2012 in the EU-30 countries.

This time the workarounds used in this paper do not correspond to the gap-filling analysis used by Extrium (4) and EEA (5). Their approach:

- use END 2012 results as reported and contained in the NOISE database (including results provided for Germany where 14 of the 16 Länder have reported);
- where results are not reported, derive END 2012 results from 2007 results inflated by the NOISE database average increase of 5.3 % for 2012 compared to 2007;
- where results have not been reported for both phases, it has not been possible to provide a quick

forecast of the estimated exposure, therefore the country has been excluded from the results (Croatia and Turkey).

2.3.3 Major roads inside END agglomerations in 2012

In theory, calculating the number of people inside agglomerations exposed to noise from traffic on major roads is simple; it's the difference between the major road data for the number of people "including agglomerations" and "outside agglomerations". In contrast to other END road noise data, the major road figures for "including agglomerations" are not in separate, consecutive noise bands (55–59, 60–64dB, etc.), but in overlapping noise bands (>55, >65 and >75). The following has been noted regarding these 2012 data:

- 24 EU-30 countries reported their major road data for 'including agglomerations'(80 %). Therefore, the 2012 data is incomplete. Major road noise data is missing for several EU countries, Cyprus, Czech Republic, Greece, Hungary and Slovenia.
- For France, for including agglomerations, there is no information for major roads with more than three million and less than six million vehicle passages per year.
- Some EU-30 countries, such as Bulgaria, Italy, Poland, Romania and Slovenia, reported major road data for "including agglomerations" and "outside agglomerations", resulting in data for "inside agglomerations" that lack credibility.

These gaps in the data had to be filled to calculate the environmental noise exposure for traffic on major roads inside European agglomerations. In case there was no (suitable) 2012 data, first the 2007 percentages for the three overlapping noise band ≥55, ≥65 and ≥75 dB L_{den} were used, assuming no change in these percentages in the period 2007-2012. To obtain 2012 data, these 2007 percentages were linked with the total number of people living inside END agglomerations in 2012. This step resulted in reliable 2012 data for four EU-30 countries (Czech Republic, Hungary, Portugal and Slovakia). Using the 2012 and 2007 data, resulted in suitable data for 21 out of 30 EU countries. For the remaining nine EU-30 countries, the number of people exposed to noise from traffic on major roads inside agglomerations in 2012 was obtained by using the EU averages for the three overlapping noise bands in the 21 countries with reliable 2012/2007 data. Unfortunately Extrium (4) and EEA (5) did no calculations for this category, so there is no possibility to compare both workarounds.

2.3.4 Non-major roads outside END agglomerations in 2012

There are 337 million people living in Europe outside the END agglomerations with more than 100 000 inhabitants. Approximately 28 million of these are exposed to noise levels of 55 dB L_{den} or more due to road traffic noise from major roads with more than three million vehicles per year. However, there are also people living along non-major roads outside the END agglomerations. The END noise mapping is of no assistance, as there is no END data on this issue. In order to obtain a valid estimation of the number of people exposed to noise from traffic on non-major roads outside the END agglomerations, a different approach is inevitable. The basic idea behind this estimation is that the number of noise exposed and annoyed people along non-major roads outside END agglomerations depends on the noise from road traffic on the non-major roads with less than three million vehicles/year and the average population density outside END agglomerations. To obtain figures on noise exposure from traffic on non-major roads outside agglomerations, the steps described in the following sections were necessary.

- ERF (2) provided road data for four categories, motorways, national roads, regional roads and other roads, in each of the EU-30 country inside and outside the END agglomerations.
- Land area outside agglomerations; the difference between the 2012 land area data in km^2 in EU-30-countries (provided by the World Bank: http://data.worldbank.org/indicator/AG.LND.TOTL.K2) and the END data about the 2012 area data in km^2 inside the agglomerations. As an average 98 % of the land area in Europe lies outside END agglomerations.
- Length major roads outside agglomerations; based on the basic assumption that in each EU-country the percentage of length of major roads outside agglomerations is the same as the percentage of land area outside agglomerations.
- Length non-major roads outside agglomerations; by subtracting the figure calculated in the previous step first from the category motorways provided by ERF (2) and, in case there are still km major roads left, by subtracting the remaining figure from the data for national roads and so on. Therefore, it provides figures in km per EU-30 country for four categories of non-major roads with less than three million vehicles/year outside the END agglomerations.
- Distance noise level contour along the different categories of non-major roads; based on expert judgement defaults for the variables that determine noise levels along these roads, like (less than

three million) vehicles per year, speed and pavement, and using the Dutch noise calculation model SRM2 to calculate the distance of the noise contours of 5 dB noise bands in the range of 55 dB L_{den} to more than 75 dB L_{den}.

- Population density outside agglomerations; based on EU data and END 2012 data. On average 65 % of the EU-30 people live outside END agglomerations.
- Noise exposure along non-major roads outside END agglomerations, a simple multiplication of the figures for the length of four different types of non-major roads with less than three million vehicles/year outside agglomerations in km per km^2, the distance of noise level contours along non-major roads outside agglomerations and the population density in inhabitants per km^2 outside agglomerations.

3. NOISE EXPOSURE AND NOISE ANNOYANCE ALONG ROADS IN EUROPE

3.1 Roads inside END agglomerations in 2012

The workarounds resulted in the number of people in 482 END agglomerations exposed to road traffic noise in the five different noise bands. In total there are approximately 76 million people living in agglomerations exposed to traffic noise levels of 55 dB L_{den} or more. This figure is somewhat lower than the outcome presented by Extrium (4) and EEA (5), i.e. almost 90 million people In contrast, the figure of 76 million is higher than the 42 million in the EU-33 countries presented by Houthuijs et al. (6).

Based on the reported and estimated 2012 data sets, the challenge is to complete the data for the five existing noise bands with data for noise bands below 55 dB L_{den}. However, there is no information on exposure of noise levels below 55 dB L_{den} on a European scale. All one can do is to make an educated guess for the percentages for noise bands below 55 dB L_{den}. A key feature is the assumption that the distribution over all noise bands has a normal distribution (see Figure 1).

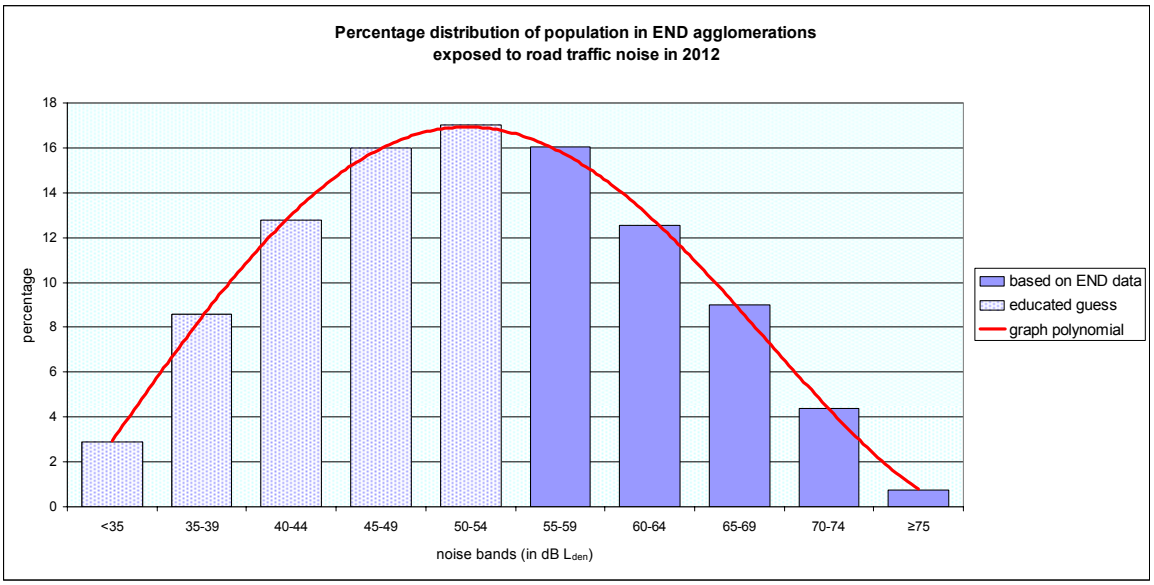

Figure 1 – END agglomeration population exposed to road traffic noise in 2012

Based on the distribution shown in figure 1, is it possible to estimate the number of people in END agglomerations exposed to road traffic noise in all 5 dB L_{den} noise bands (see Table 2).

Table 2 – Number of people in agglomerations exposed to road traffic noise in 2012.

	noise exposure from traffic on roads in END agglomerations in EU-30 countries in 2012 in 5 dB Lden noise bands (in million)										
numbers:	<35	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	≥75	total
based on data						28.5	22.3	16.0	7.7	1.4	178
educated guess	5.2	15.3	22.7	28.4	30.2						

Using the distribution illustrated in figure 1, the numbers presented in table 2 and standard Microsoft Excel high order polynomial trendline analysis, it is possible to calculate the number of people in END agglomerations exposed to road traffic noise in 1 dB L_{den} noise bands. Based on these 1 dB L_{den} noise band data for noise exposed people, it is now possible to estimate the number of noise annoyed people in the END agglomerations in 2012. The calculations of noise annoyed people is based on the L_{den} version for noise annoyance by road traffic noise (%A) from Miedema and Oudshoorn (7). Consequently, almost 32 million of the 178 million people living in END agglomerations are annoyed by road traffic noise. Therefore, in 2012 one out of five persons living in European agglomerations is annoyed by road traffic noise.

3.2 Roads outside END agglomerations in 2012

The workarounds described in paragraph 2.3.2, resulted in the EU-30 figures for major road noise exposure outside agglomerations. In Europe, the figures for the 337 million people living outside agglomerations and exposed to major road traffic noise of 55 dB L_{den} or more in 2012 is low (approximately 28 million or 8 %). The explanation is clear;. most of the population outside agglomerations does not live in close proximity to major road infrastructure. For the majority, noise levels by major road traffic will be low (less than 40 dB L_{den}).

Initially, the figure of 28 million people appears out of line with the outcome presented by Extrium (4) and EEA (5): almost 36 million people. However, at the level of individual EU countries there are significant differences. For example, Extrium/EEA calculates almost 18 million people living along major roads in the United Kingdom outside agglomerations exposed to noise levels of 55 dB L_{den} or more: while in this paper, the calculations resulted in approximately 4 million people.

The low percentages for high noise levels indicate a fundamental difference between the proportionate distribution of noise exposure along major roads outside agglomerations and the proportionate distribution of noise exposure along roads inside agglomerations. For the proportionate distribution of noise exposure along roads inside agglomerations, the distribution will show a more or less normal distribution (see Figure 1). The proportionate distribution of traffic noise exposure along major roads outside agglomerations however, will show an exponential distribution.

Based on the reported and estimated 2012 data, the challenge is to complete the data for the range of the five existing noise bands with data for noise bands below 55 dB L_{den}. However, there is no European information on exposure of major road noise levels below 55 dB L_{den}: an educated guess can be made for the percentages for noise bands below 55 dB L_{den} (see Figure 2).

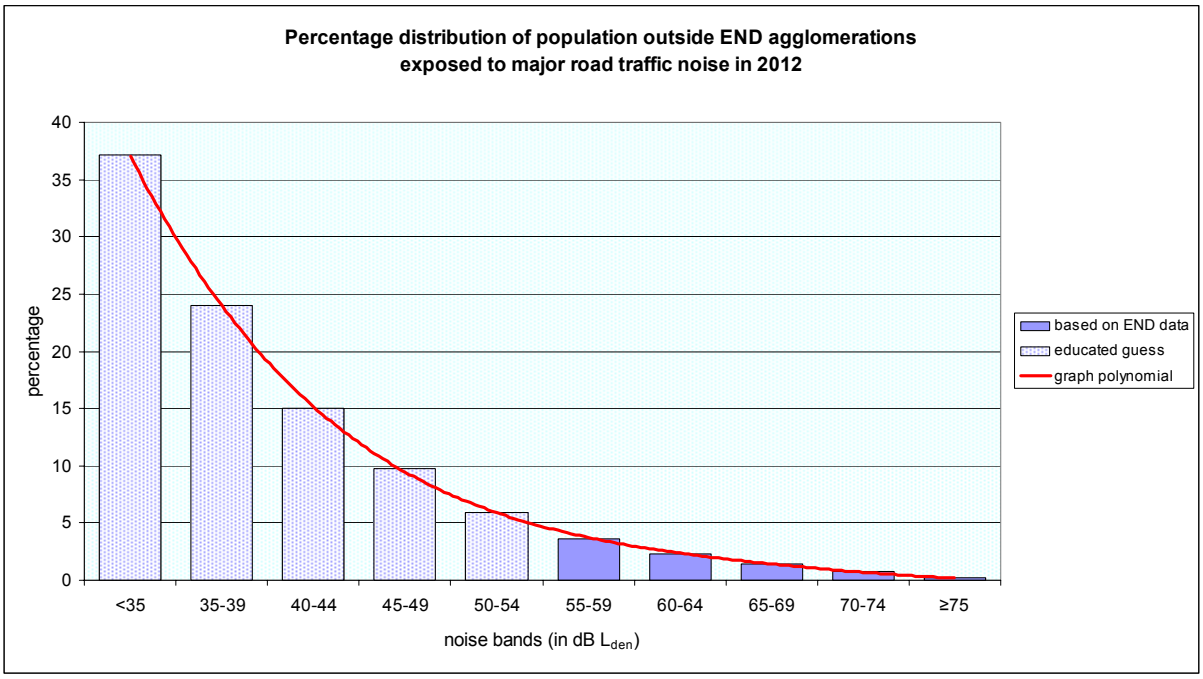

Figure 2 – Population outside END agglomeration exposed to major road traffic noise in 2012

Based on the distribution shown in figure 2, the numbers of people outside END agglomerations

exposed to major road traffic noise in all L_{den} noise bands were calculated (see Table 3).

Table 3 – Number of people outside agglomerations exposed to major road traffic noise in 2012.

	noise exposure from traffic on major roads outside END agglomerations in EU-30 countries in 2012 in 5 dB L_{den} noise bands (in million)										
numbers:	<35	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	≥75	total
based on data						12.2	7.9	4.9	2.4	0.6	337
educated guess	125.1	80.9	50.6	32.7	19.9						

Using the same approach as for noise exposure from roads inside agglomerations (see par. 3.1), it possible to estimate the number of road noise exposed outside END agglomeration population in 1 dB noise bands and the number of people outside agglomerations in 2012 annoyed by major road traffic noise. The calculations demonstrate that 16 million or 5 % of the 337 million people living outside END agglomerations are annoyed by major road traffic noise.

3.3 Major roads inside agglomerations in 2012

Based on the adjusted 2012 END data (see par. 2.3.3), the challenge this time is to complete the estimated numbers and percentages of the three overlapping noise bands (≥55, ≥65 and ≥75 dB L_{den}) with data for 5 dB noise bands above and below 55 dB L_{den}. As there is no information on noise exposure by major road traffic noise inside agglomerations of levels below 55 dB L_{den} on a European scale, an educated guess can be made for the percentages for noise bands below 55 dB L_{den}. A key feature is the assumption that the proportionate distribution over all noise bands for traffic noise exposure along major roads in agglomerations has a exponential distribution, comparable with the one for noise exposure along major roads outside agglomerations. After some trail and error, it was possible to calculate the number of people exposed to noise from traffic on major roads inside END agglomerations in 2012 (see Table 4).

Table 4 – Number of people inside agglomerations exposed to major road traffic noise in 2012.

	percentages and number of people inside END agglomerations exposed to major road traffic noise in different dB L_{den} noise bands in 2012									
	<40	40-44	45-49	50-54	55-59	60-64	65-69	70-74	≥75	total
based on data (in %)					12.0		4.7		0.4	17.1
educated guess (in %)	38.9	22.0	13.0	9.0	6.8	5.2	3.3	1.4	0.4	100.0
number of people (in million)	69.1	39.1	23.1	16.0	12.2	9.1	5.8	2.5	0.8	178

There are 178 million people living in the END agglomerations in 2012; 30 million of them are exposed to major road traffic noise of 55 dB L_{den} or more. Some of these 30 million people are also exposed to noise for traffic on non-major roads in agglomerations. However, the END noise mapping data offers no support in dealing with this overlap.

Using the same approach as for noise exposure from roads inside agglomerations (see par. 3.1), it possible to estimate the number of major road noise exposed people inside agglomerations in 1 dB noise bands and the number of people inside agglomerations in 2012 annoyed by major road traffic noise. The calculations show that 15 million or 5 % of the 178 million people living inside END agglomerations are annoyed by major road traffic noise.

3.4 Non-major roads outside END agglomerations in 2012

The approach described in paragraph 2.3.4, makes it is possible to calculate the number of people exposed to road traffic noise along the non-major roads outside the END agglomerations. The final output provides figures for each EU-30 country for the figures for the number of people exposed to noise from traffic on non-major roads with less than three million vehicles/year outside agglomerations in 5 dB noise bands in the range from 55 dB L_{den} to more than 75 dB L_{den} (see Table 5).

Therefore, there are approximately 36 million people living outside agglomerations that are exposed to noise levels from traffic on non-major roads with less than three million vehicles/year. In END noise mapping, this category is ignored. However, these 36 million people are a substantial group of people.

Table 5 – Number of people outside agglomerations exposed to non-major road traffic noise in 2012.

	number of people outside END agglomerations in 2012 exposed to noise from traffic on non-major roads with less than 3 million vehicles/year in dB L_{den} noise bands (in million)					
	55-59	60-64	65-69	70-74	≥ 75	≥ 55
number of people	15.9	15.2	4.4	0.2	0	35.7

Outside the END agglomerations, people are not only exposed to road noise from traffic on non-major roads with less than three million vehicles/year, but also from traffic on major roads with more than three million vehicles/year. Although there is a small overlap between these two groups, is interesting to add both groups together. The adding shows that there are approximately 64 million people living outside agglomerations exposed to road traffic noise levels of 55 dB or more. That is 19 % of the total population living outside END agglomerations.

As for noise annoyance along non-major outside the END agglomerations, there is a big difference between the possibilities of calculating the number of people annoyed by road traffic noise below and above 55 dB L_{den}. For the range of 55 dB L_{den} and more up to more than 75 dB L_{den}, the limited figures for non-major roads noise exposure makes it possible to calculate approximate numbers for noise annoyance along non-major roads outside the END agglomerations. Finally, the calculation for the range of 55 dB L_{den} and more up to more than 75 dB L_{den} resulted in 10 million noise annoyed people living along non-major roads outside the END agglomerations in 2012.

With the present data set, it is not possible to calculate the number of people exposed to traffic noise below 55 dB L_{den} along non-major roads outside agglomerations. Therefore, there are no means to calculate the number of noise annoyed people along the non-major roads. However, an assumption can be made that there is no significant difference between the number of noise annoyed people along major roads and noise annoyed people along non-major roads. There are two indications supporting this: firstly, the comparable numbers of noise exposed people along non-major roads and major roads in the noise bands in the range of 55 dB L_{den} and more up to more than 75 dB L_{den} (see Tables 3 and 5). And secondly, the assumption that both distributions of noise exposed people have an exponential distribution. Based on this, the number of noise annoyed people along non-major and major roads outside END agglomerations in 2012 is the same, i.e. 16 million. For all roads outside agglomerations the total number in 2012 is 32 million.

3.5 Reduction of people exposed to and annoyed by road traffic

The datasets for noise exposed people described in the previous paragraphs enables the effect of noise reduction to be estimated on a European scale. The concept entails a shift in the total amount of noise exposed people, from a higher noise band to a lower noise band, throughout the entire range of 1 dB noise levels. A 1 dB reduction has a significant effect of an 8 % decrease of the amount of people in the END agglomerations exposed to traffic noise levels of 55 dB L_{den} or more. A 2 dB reduction results in 15 % less people exposed to traffic noise levels of 55 dB L_{den} or more. This demonstrates the potential on noise exposure decrease of implementing noise reducing measures on a European scale.

The new datasets of noise exposed people is used to recalculate the new amount of noise annoyed people in each 1 dB noise band. The example of different reductions is illustrated in Figure 3.

A 1 dB reduction has a significant effect of an 8 % on the amount of noise annoyed people living in the END agglomerations. A 2 dB reduction results in 15 % less noise annoyance. For the other categories, people outside and inside agglomerations annoyed by noise from traffic on major roads, the reduction percentages are more or less the same. Like the reduction of noise exposure, this demonstrates the potential noise annoyance decrease of implementing noise reducing measures on a European scale.

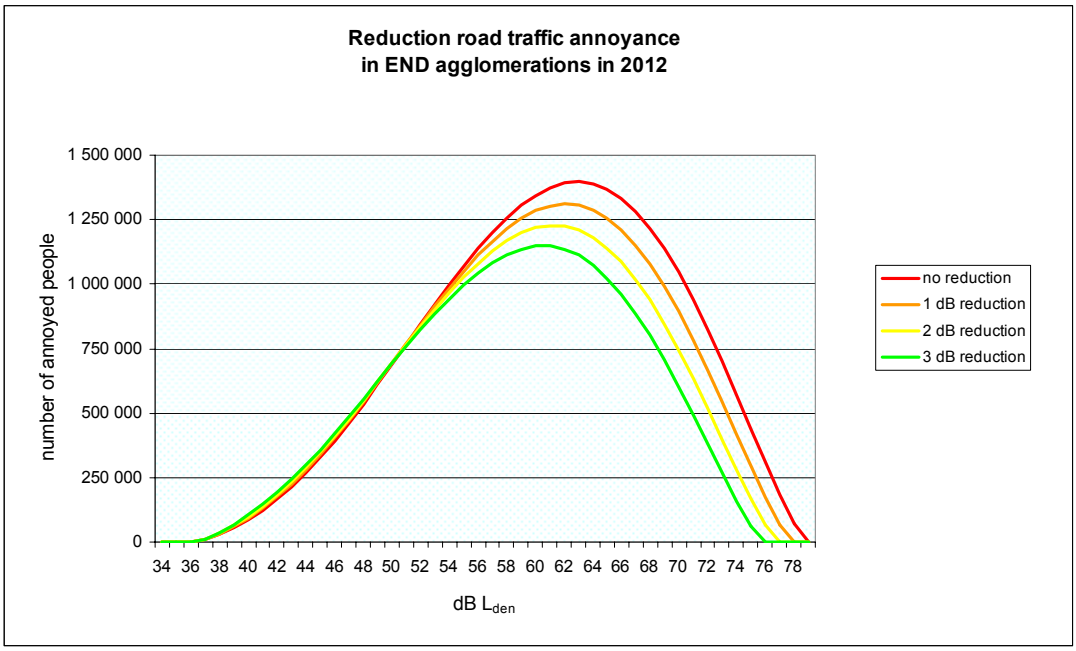

Figure 3 – The effect of noise reduction on the amount of noise annoyed people in END agglomerations

3.6 Road traffic noise exposure in Europe in 2012

The information presented in the previous chapters, offers the opportunity to present figures for noise exposure and noise annoyance by road traffic in Europe in 2012 based on END data and some other data sources. Based on END data, the figures for noise exposure in the range of 55 dB L_{den} and more up to more than 75 dB L_{den} by road traffic in Europe is 2012 are presented in Table 6.

Table 6 – Number of noise exposed people living along roads in EU-30 countries in 2012

	number of people exposed to road traffic noise in 2012 in dB L_{den} noise bands (in million)						total inhabitants:		
road traffic on:	55-59	60-64	65-69	70-74	75 dB	≥ 55 dB	inside agglom.	outside agglom.	EU-30 countries
all roads inside END agglomerations	29	22	16	8	1	76	178		
all roads outside END agglomerations	28	23	9	3	1	64		337	
all roads in EU-30 countries	57	45	25	10	2	140			515
major roads in EU-30 countries	24	17	11	5	1	58			515

In 2012, there are approximately 140 million people in Europe exposed to road traffic noise levels of 55 dB L_{den} and more. Therefore, one out of four persons living in Europe is exposed to high road traffic noise levels. Of these 140 million, 58 million people are exposed to high noise levels due to traffic on major roads.

3.7 Road traffic noise annoyance in Europe in 2012

The total figures for noise annoyance by road traffic in Europe in 2012 are presented in Table 7.

Table 7 – Number of noise annoyed people living along roads in EU-30 countries in 2012

	number of people annoyed by road traffic noise in in 2012 (in million)	total inhabitants:		
road traffic on:		inside agglom.	outside agglom.	EU-30 countries
all roads inside END agglomerations	32	178		
all roads outside END agglomerations	33		337	
all roads in EU-30 countries	64			515
major roads in EU-30 countries	31			515

In 2012, there are approximately 64 million people in Europe annoyed by road traffic noise levels ranging from 30 dB L_{den} to more than 75 dB L_{den}. Therefore, one out of eight persons living in Europe is annoyed by road traffic noise. Of these 64 million, 43 million are annoyed due to noise levels of 55 dB L_{den} or more. Almost half of the 64 million (31 million people) are annoyed by road traffic on major roads.

4. RELIABILITY ROAD TRAFFIC NOISE EXPOSURE FIGURES

4.1 Different noise calculation methods in European member states

Throughout Europe, various methods are used to calculate road noise levels. There is the French NMPB, the Dutch RMW, the Scandinavian Nord, the English CRTN and in German speaking countries VBUS, StL and RVS. Despite the input being the same, the output of these models differs up to 15 dB(A), depending on the situation according to Nijland (8). This is due to different national calculation methods, different implementation of the methods in software packages and different interpretations of the acoustical situation by the experts using the methods. Overcoming these differences, was the driving force behind developing and regulating the new European noise calculation models, Common Noise Assessment Methods in Europe (CNOSSOS-EU), as mentioned for the first time in EC (9). Developing CNOSSOS-EU was a lengthy process and not without obstacles (10). On 1st July 2015, after approximately ten years, the common noise assessment methods were published in the Official Journal of the European Union (11). Member states are required to use CNOSSOS-EU from 31st December 2018 onwards.

4.2 Gaps in END noise mapping data

It should be noted that significant gaps remain in END data, because some data has not yet been reported by member states. Regarding the network of roads, "it is (…) extremely difficult to be sure that the entire network (…) have indeed been included in the calculation of noise maps" (12). To date, the 2012 and 2017 END datasets have missing data.

While missing data is problematic, the quality of some reported data also causes difficulties. The data quality assessment system adopted by EEA/ETC-ACM for the NOISE website is not rigorous enough to identify discrepancies within reported END datasets. To improve data quality, government authorities, such as the NRA, should assess the quality of their END data before they report to the competent authority in their member state (13). Complete and unbiased data is essential, because the END noise exposure data are the driving force in noise abatement on a European level as well as on a national level.

4.3 Workarounds to estimate missing END noise mapping data

Provided that not all EU countries have sent information on the strategic noise maps concerning the second round of the END, workarounds proved necessary to estimate missing END data. The inclusion of assumptions and premises was inevitable in the process of tracing missing END data, especially in the range of noise levels below 55 dB L_{den}. At the very least, educated guesses are used to support these assumptions and premises. Consequently, the reliability of the noise exposure figures above and below 55 dB L_{den} is somewhat different. Recalculating noise exposure and noise annoyance with future END noise mapping data deliveries, is necessary. Therefore, the NOISE website should be checked periodically for new END data uploads and to recalculate the noise exposure figures in case there is a new upload of END data. As for the range of noise levels below 55 dB L_{den}, using other assumptions and premises in recalculating noise exposure will probably produce slightly different figures. Therefore, in the range below 55 dB L_{den} the reliability is not as high as in the range above 55 dB L_{den}. A Monte Carlo analysis would help to deal with uncertainties in the noise exposure figures in the range below 55 dB L_{den}. In this report, the focus in noise exposure and noise annoyance is on the range of 55 dB L_{den} or more, so the need to perform such an analysis is limited.

4.4 Future developments

During the third round END noise mapping in 2017, it is highly likely the national calculation methods will still be used. From 2018 onwards, END noise mapping throughout Europe has to be based on the noise calculation methods, CNOSSOS-EU. The first results of road traffic noise exposure figures based on using CNOSSOS-EU will be available in 2022–2023.

5. PRACTICAL IMPLICATIONS FOR CEDR NATIONAL ROAD AUTHORITIES

The outcome of processing the END data provides figures on (major) road traffic noise exposure and annoyance in Europe in 2012. For the NRAs cooperating in the CEDR, the END figures presented in this report plot a course for a common CEDR noise policy regarding the implementation of noise reducing measures such as noise reducing pavements and noise barriers. Guiding principle should be the cost-effectiveness of these measures, i.e. to attain as much noise reduction as possible, at the lowest cost.

Firstly, these figures are useful in optimizing the practical application of noise reducing measures by CEDR NRAs, e.g. in END action plans. Road traffic is expected to increase in the future. Unless NRAs implement noise reducing measures, noise levels alongside road infrastructure will also increase. The best method to deal with the challenge of reducing road traffic noise in a cost-effective manner, is to concentrate the use of noise reducing measures on major roads inside the END agglomerations. The high population density, the limited length of major roads inside agglomerations and the high noise levels along these roads, provide a cost-effective opportunity for NRAs to use noise reducing pavements on these major roads and to place noise barriers at hot spots along these roads.

Secondly, the END figures show the potential for the reduction of noise exposure and noise annoyance. Milford et al. (14) showed that for NRAs silent vehicles and silent tyres are the most cost-effective noise reducing measures. The Regulation 661/2009 on silent tyres (15) and the Regulation 540/2014 on silent vehicles (16) were intended to reduce road traffic noise in Europe. In terms of traffic noise reduction, the future outcome of these EU regulations is limited. For example, in relation to silent vehicles, the effect of this EU regulation is a reduction of approximately 1 dB in the next ten years and a maximum of 2,5 dB in 2035 (see Figure 4, based on de Roo and Dittrich (17)).

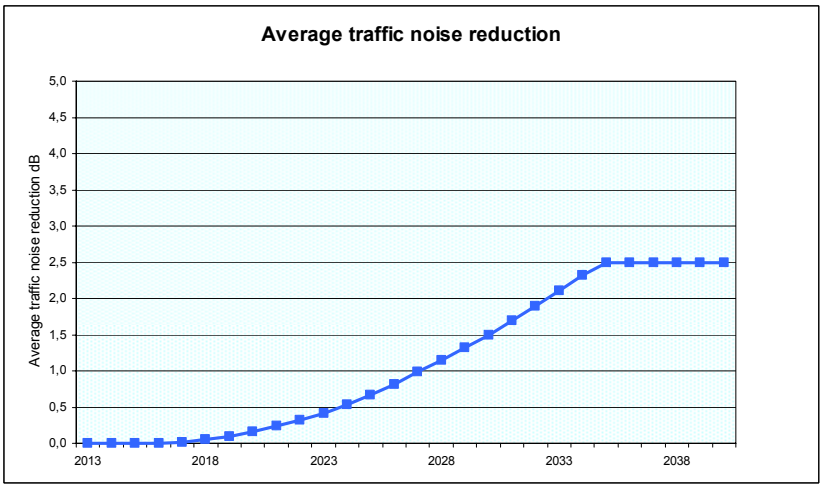

Figure 4 – Estimated road traffic noise reduction due to EU regulations for silent vehicles (17).

To handle road traffic noise, NRAs use their standard noise measures: noise reducing pavements, noise barriers and façade insulation. However, compared to silent vehicles and silent tyres, these standard noise measures are less cost-effective. That is why the CEDR organization invites the vehicles and tyre industry to cooperate closely on the common challenge to improve the future outcome on traffic noise reduction by vehicles and tyres.

6. MAIN CONCLUSIONS

The main conclusions regarding the use of END data for estimating the number of road noise exposed and annoyed people in the EU-30 countries in 2012 are:

- Approximately 140 million of the 515 million EU-30 inhabitants in 2012 - one out of four - are exposed to road traffic noise levels of 55 dB L_{den} or more.
- In 2012, approximately 64 million of the EU-30 inhabitants - one out of eight - are annoyed by road traffic noise.
- Traffic on major roads causes approximately half of the total noise annoyance by road traffic.

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